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Water Plant Waste Discharge in the Province of Ontario

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Enquiries pertaining to the Canada-Ontario Agreement RESEARCH PROGRAM should be directed to -

Wastewater Technology Centre
Canada Centre for Inland Waters
Fisheries and Environment Canada
P.O. Box 5050
Burlington, Ontario L7R 4A6

Ontario Ministry of Environment
Pollution Control Branch
135 St. Clair Avenue West
Toronto, Ontario M4V 1P5

WATER PLANT WASTE DISCHARGE
IN THE PROVINCE OF ONTARIO

by

W.R. Hutchison, A.P. Galati and Z.K. Khan
Ontario Ministry of Environment

RESEARCH PROGRAM FOR THE ABATEMENT
OF MUNICIPAL POLLUTION UNDER THE
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ABSTRACT

A survey of 105 water treatment plants in the Province of Ontario was carried out to determine the characteristics of their wastewater discharges. The survey included compilation of raw water data, operating parameters and available treatment facilities. A variety of chemical and physical tests were performed on the wastewaters leaving more than 35 of the plants.

On an average day in Ontario in 1973, 19.3 MIG (87,827 m^3) of wastewater containing 85,400 lb (38,765 kg) of solid waste were discharged into Ontario's waterways. The quality of the wastes varied widely between water plants. The wastes discharged from the sedimentation or clarification sections of the plants had the highest levels of the measurable polluting materials. The filter wash water characteristics were similar to local river waters after heavy rains.

A cost estimate of the appropriate methods for collecting, treating and disposing of the wastes was made. The estimated annual cost of collecting, treating and disposing of all waste discharges from water plants throughout the Province of Ontario was approximately 6.5 - 7.8 million dollars based on December, 1973 costs.

RÉSUMÉ

Nous avons examiné les rejets de 105 usines de traitement des eaux usées de la province de l'Ontario. A cette occasion, nous avons recueilli des données sur les eaux brutes, les paramètres d'exploitation et les traitements réalisés. Nous avons fait une variété de tests chimiques et physiques sur les effluents de plus de 35 de ces usines.

En 1973, au cours d'une journée normale, 19.3 x 10^6 gallons impériaux (87 827 m^3) d'eau usée contenant 85 400 lb (38 765 kg) de matières solides étaient rejetés dans les cours d'eau de l'Ontario. La qualité de ces eaux variait grandement d'une usine de traitement à l'autre. Les rejets des bassins de décantation ou des clarificateurs étaient les plus pollués. L'eau de lavage des filtres était semblable par ses propriétés à celle des rivières locales, aprés de fortes pluies.

Nous avons fait une estimation des coûts des méthodes appropriées pour recueillir, traiter et éliminer les déchets. Au cours du dollar de décembre 73, ces opérations appliquées à tous les rejets des usines de traitement de l'eau de la province de l'Ontario auraient coûté environ 6,5 à 7,8 millions de dollars par année.

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SUMMARY

This report discusses the quantity and quality of the wastewater being discharged from water treatment plants throughout the Province of Ontario in 1973. On an average day in 1973, an estimated 85,400 lb (38,765 kg) of solid waste material contained in 19.3 MIG (87,827 m^3) of liquid waste was discharged from water works throughout the Province.

A total of 105 water treatment plants were surveyed in an in-depth study which included sampling, interviews with plant operating personnel and a questionnaire. A variety of chemical and physical tests were carried out on the wastewaters being discharged from more than 35 water plants. The quality of the waste varied widely, depending on a number of factors including raw water quality and chemical addition. Wastewater discharges were found to range from backwash water containing 10 - 20 mg/l of suspended solids to sedimentation basin sludge containing more than 20,000 mg/l of suspended solids. Similar variations were found for other chemical and physical constituents. The environmental impact on the receiving stream of the discharge of the wastewater is not known.

A review of the literature was carried out to determine the existing technology for the collection, treatment and disposal of wastewater from water plants. Only 10 of the 105 existing water plants treated any portion of their wastewater in 1973. As did the most common disposal methods described in the literature, all 10 plants either discharged their waste into the sanitary sewer or into lagoons.

The cost of modifying existing water works to provide for waste collection, treatment and disposal, would require capital expenditures of over 50 million dollars (mid-1975). The annual operating cost including amortization of the capital cost was estimated at 8 to 10 million dollars (mid-1975).

RECOMMENDATIONS

(1) An environmental assessment should be carried out to study the effect of water works waste on receiving streams at a minimum of three locations in each of the six Ontario Ministry of the Environment Regions within the next two years.

(2) The information gathered in the minimum of 18 environmental assessments outlined in recommendation (1) should be summarized by a person or committee and recommendations for the treatment of wastewater from existing plants should then be made.

(3) Studies should be carried out at the selected plants concurrent to the environmental assessment to determine the cost to collect, treat and dispose of the wastewater originating in the selected plants. These studies should include a discussion regarding methods of reducing the quantities of waste.

(4) Representative samples of waste sludges and backwash water should be collected from all water works on a routine basis, preferably four times a year, and submitted to the laboratory for analyses. An estimate of the quantity of waste should also be made, especially for those plants where sedimentation and clarification facilities are used. The program should be initiated by all Regional Offices.

(5) The present disposal practices of the water treatment plant sedimentation basin wastes should be modified to minimize the environmental impact of the waste. The modification could include more frequent cleanings of the basins, cleaning during high water flow for those plants on the river or trucking the sludge from a well drained basin.

(6) The effect of disposing alum sludges and polymer sludges on land as a soil conditioner should be studied.

(7) Inspection reports on all water works throughout the Province of Ontario should include estimates of the wastewater quantity (volume and weight of solids), peak waste production and variation in waste quality.

DISCUSSION

Investigations were carried out on the wastewater discharge practices of 105 water treatment plants in the Province of Ontario, in 1973. Most of these water works are designed primarily to remove turbidity (63 plants) or colour (30 plants) from the raw water. Approximately half (51) of the 105 water plants are located on the Great Lakes.

On an average day in 1973, the water plants were estimated to discharge approximately 19.3 MIG (87,827 m^3) of liquid waste containing 85,400 lb (38,765 kg) of solid waste material.

Physical analyses of wastewater indicated that the quality of the waste was highly variable between plants and between the various treatment sections within a given plant. Suspended solids in most backwash waters were typically in the 500 to 1,000 mg/l range. However, during periods of high raw water turbidity suspended solids concentrations of over 4,000 mg/l were found.

Average concentrations of sedimentation basin sludge ranged from 10,000 mg/l of suspended solids for water plants on rivers to over 50,000 mg/l of suspended solids for several plants located on Lake Ontario. These were samples taken from drained sedimentation basins. For on-site estimates the sludge discharged into the receiving stream was usually calculated to be diluted by a factor of 2:1 by high pressure hoses.

Chemical analyses of the wastes revealed that the backwash waters are usually quite low in BOD_5 (< 10 mg/l), total phosphorus (< 10 mg/l), and nitrate (< 0.2 mg/l). Sedimentation and clarifier sludges, on the other hand, were found to be as high as 6,000 mg/l BOD_5, 300 mg/l total phosphorus and 3.0 mg/l of nitrate.

There is little doubt that the discharge of sedimentation basin waste or clarifier waste from the water works does not disturb the quality of aquatic life near the outfall. However, the effect of the backwash water on the environment is not known and both types of wastewater may require treatment.

Backwash water was found to contain suspended solids, phosphorus and BOD_5 levels similar to those found in several rivers draining agricultural land or near industrialized areas.

An example that illustrates this point is the situation around the Metropolitan Toronto Area. The total average daily flow of the four plants in this area was 46.5 percent of the average daily water production of the plants producing waste throughout the Province of Ontario. The backwash water of three of the plants was sampled and calculations of the quantity of suspended solids, BOD_5, and total phosphorus for all four plants discharging into Lake Ontario with the backwash water in 1973 were made. This total was then compared to the discharge of the Humber River into Lake Ontario in one day after a heavy spring rain.

The results were as follows:

Source/constituent	Suspended Solids	BOD_5	Total Phosphorus
Four Water Plants			
mg/l	70-365	3-25	0.3-1.1
lb/day	9,000	700	50
Humber River			
mg/l	460	7.6	1.5
lb/day	1,000,000	28,600	1,580

A comparison of the two sets of results indicates that, after a heavy rain, the Humber River discharges into Lake Ontario in one day an amount of suspended solids (SS) equal in weight to the amount of SS discharged into the Lake over an average 111 day period from the four water works.

Similarly, the weight of BOD_5 and total phosphorus discharged into Lake Ontario from the Humber River is equivalent to the weight of BOD_5 and total phosphorus contained in 40 days and 31 days, respectively, of backwash water waste discharged from the four water works around the Metro area. This comparison does not diminish the significance of water works backwash water but rather puts the quantity of wastewater being discharged from water works into perspective.

The water plant waste and the receiving water differ significantly in aluminum content. Unfortunately little work has been published on the effect of aluminum on aquatic life. In 1973, water works discharged 5,000 - 6,000 lb (2268 - 2721 kg) of aluminum, in various states of oxidation, into the waterways. Probably, a similar weight was discharged from other sources such as industrial or sewage treatment plants.

Only 10 of the 105 water plants surveyed treat any portion of their wastewater. All ten plants discharged their waste either into the sanitary sewers or into a retention lagoon. For many plants with no waste treatment, only one of these methods of disposal is feasible. Modifying the plants to collect, treat and dispose of the waste would increase the annual cost of treating the water. Waste treatment could lead to other problems such as loss of reserve capacity of the sewage treatment plant, a reduction in the aesthetic appearance of the water works by the presence of a lagoon, or a disturbing frequency of truck traffic to haul dewatered sludge.

The cost of treating water works waste in 1975 dollars could be 50 - 60 million. The average annual operating costs are expected to be close to 8 - 10 million 1975 dollars.

Action should be initiated in two areas. One concerns the environmental effect of the waste discharge: Is it a problem to all receiving streams? What portion of the waste should be treated? Would the expenditures be better put to use upgrading the municipal and Ministry of the Environment pollution control plants?

The second area concerns the research and development of water treatment. Can the metal based coagulants be replaced by polymers, thereby reducing the solids in the waste and facilitating the disposal of sludge on nearby land? Are there ways of reducing the waste quantity by optimizing the treatment process or by reducing the production of the water plants?

This above action should be coordinated and should involve participation of personnel from Ontario Ministry of the Environment Regional Offices, municipal representatives and consulting engineers. The answers to many questions are needed before any extension of the existing legislation for water works waste can be contemplated.

1. INTRODUCTION

The main purpose of this report was to assist the Province of Ontario to determine the status of the wastes leaving the water treatment plants in Ontario. The Ontario Ministry of the Environment introduced restrictions on the water plant waste discharges of newly constructed or upgraded plants in 1972. The waste effluent leaving these plants is to be treated as sewage and have sedimentation as the minimum treatment.

Many authors have studied the waste discharged throughout the United States and Canada. This report complements this earlier work and, at the same time, gives waste volumes, weights and other characteristics specific to Ontario. The methods of collection, treatment and disposal of wastewaters are as numerous as the engineers who design them. Methods for wastewater disposal could be determined if specific information on the water works waste in Ontario was obtained. Only then could a realistic cost estimate to reduce this waste discharge be made.

The collection of information on water plant wastes is only one facet of the entire picture. As this report progressed the need for some statement on the environmental impact of these waste discharges became apparent. A thorough search of the literature revealed a notable lack of information on the environmental impact. The effects of waste characteristics such as biochemical oxygen demand (BOD_5), nitrates and suspended solids on the environment have been established for sewage plant effluents [1]. However, little work has been done on determining the levels of these waste parameters in water plant effluents such as sedimentation tank flushings, clarifier blowdown or filter backwash.

Some work has been done on the effects of metals such as zinc, copper and aluminum on the fish life of the receiving stream but little information has been gathered within the province on what levels are encountered in water plant discharges and how they are related to the laboratory work [2, 3].

Regulatory agencies of States surrounding Ontario's southern lakes were contacted and, although they have regulations similar to those introduced by Ontario in 1972, there was no information on the environmental impact of the wastes [4].

The other aspect of the wastewater question that was difficult to assess was the willingness of the public to back demands for water waste treatment which could result in substantially higher water rates. It is well known that the public has a growing awareness of both pollution and problems related to pollution. Tours by school groups through water plants are marked by questions about the wastewater discharges. However, as the authors of this report have observed, the need for treating all water works waste has not been clearly defined.

1.2 Project Objectives

The four main objectives of the research program were to:

1) Determine the characteristics of existing water treatment plants (WTP).
2) Determine the chemical, physical and bacteriological characteristics of the WTP wastes.
3) Assess the current developments in methods of treatment or reduction of water plant waste discharge.
4) Estimate the capital and operating costs of providing for the disposal of the WTP wastes.

1.2.1 Objective one

Determine the characteristics of existing water treatment plants.

The parameters of the plant should include:

1) the raw water characteristics,
2) the chemicals used,
3) the treatment facilities,
4) the quantity of sludge produced,
5) the physical feasibility of various sludge disposal methods.

1.2.2 Objective two

Determine the chemical, physical and bacteriological characteristics of the WTP wastes.

Wastewater characteristics were expected to be highly variable and would come from four main sources.

The sources examined were:

1) screen waste,
2) microstrainer wash,
3) sedimentation basin or clarifier blowdown,
4) filter backwash.

The following tests were carried out.

1) Physical Analyses:
   viscosity,
   density,
   solids,
   settling time.
2) Chemical Analyses:
   biochemical oxygen demand,
   chemical oxygen demand,
   pH, sulphates,
   Kjeldahl nitrogen, nitrates, phosphates,
   alum, arsenic, lead,
   trace metals (chromium, zinc, copper, mercury, cadmium, nickel, manganese).
3) Bacteriological
4) Total Bacteria Plant Count

1.2.3 Objective three

Assess the current developments in methods of treatment or reduction of water plant waste discharge.

This objective was to be carried out by an intensive search of all current literature while the water plant study was taking place. If possible, all relative findings from the literature search were to be applied to the wastewaters on a bench scale basis.

1.2.4 Objective four

Estimate the capital and operating costs of providing for the disposal of the WTP wastes.

The data obtained by the Canada-Ontario Agreement (COA) personnel were to be placed in a form that was easily retrievable. Consultants were engaged to review the data with COA personnel to obtain sufficient information to determine:

1) the cost of plant modifications
2) the cost of collection facilities
3) the cost of treatment and disposal

In addition, plant models were to be constructed to simulate the costs involved in a typical turbidity and a typical colour removal plant.

Cost determining data were to be summarized in a form that would allow any typical water treatment facility to assess its general costs for its particular plant.

A cost figure for the province, regions and waterways was also to be supplied.

1.3 Plan of Attack

Surveys carried out in the past by a questionnaire have been incomplete, mainly because of poor response and/or insufficient data available. For this reason, a personal visit by COA personnel to a representative number of plants was carried out. In addition, a questionnaire was distributed to the main plants. A copy of this questionnaire is given in Appendix I.

Table 1 outlines the size range classification of these water treatment plants. A review of this table reveals that 73.3 percent of the water processed by water plants in Ontario was concentrated in just 10 plants. Those plants producing less than 5 MIGPD (22,748 m^3/day) numbered 81 but they produced only 11.4 percent of the Province's water.

Because of the heavy weighting of any findings by the large water plants, special emphasis was placed on these plants as well as those in the 5 - 20 MIGPD (22,748 - 90,905 m^3/day) range. This special emphasis took the form of plant sampling and examination of the daily records. Selected smaller [less than 5 MIGPD (22,748 m^3/day)] water plants were examined closely as well. These plants were to be representative typical colour and turbidity removal plants.

A complete listing of all plants surveyed is given in Appendix II.

TABLE 1. WATER PLANT SIZE RANGE BREAKDOWN*

Size Range MIGPD	Number of Plants	Water Production 1973 Average MIGPD	%
> 20	10	537.0	73.3
5-20	14	111.8	15.3
0.5-5	45	74.2	10.0
< 0.5	36	10.0	11.4
Totals	105**	733.0	100.0

* All tables have been converted into metric units and are located in Appendix IX.

** Total number of water plants producing wastes in Ontario in 1973.

1.3.1 Questionnaire and sampling

An eighteen page questionnaire, which when completed would give the details on raw water conditions, chemicals used and operating facilities and characteristics in the water plant was drawn up.

Because of the heavy weighting of the larger water treatment plants of the overall provincial picture, the questionnaire for these plants was completed by interview with the chief operator or superintendent. At the same time the wastes leaving 34 water plants were sampled and returned to the laboratory for analyses. The wastewaters included the filter backwash, sedimentation basin sludge or clarifier blowdown and microstrainer discharge.

While on location at these plants, the chief operators or superintendents at 31 nearby water plants were also interviewed.

Forty questionnaires were sent out to smaller remotely located water plants. From those 40 plants the response was about 50 percent. Follow-up by telephone and reissue of the questionnaire elicited information from all but four plants. These plants had their questionnaires completed by COA personnel using Toronto based files.

Table 2 indicates how the information was gathered for all 105 water plants surveyed. This is tabulated into the four size ranges that represent the average daily flow for 1973.

TABLE 2. WATER PLANT SURVEY BREAKDOWN

1973 Average Daily Flow MIGPD	Number				Water Production			
	Total	Quest. only	Visit	Sample	Total MIGPD	Quest. only	Visit	Sample
> 20	10	0	0	10	537	0.0	0.0	537.0
5-20	14	0	7	7	112	0.0	63.0	49.0
0.5-5	45	15	19	11	74	21.5	32.0	20.5
< 0.5	36	25	5	6	10	5.8	1.7	2.5
Total	105	40	31	34	733	27.3	96.7	609.0

1.3.2 Literature search

Throughout this project, pertinent literature was accumulated and regularly updated.

The main areas of interest were the environmental effects of the wastewater discharge and the waste treatment and disposal methods. All information found is discussed in Section 2 of this report. The waste treatment disposal systems either in use or under study are discussed in detail in Section 4. The work in this field is extensive and developments are occurring continuously. All papers pertaining to water works waste are listed in a cross reference file in Appendix III.

2. WASTEWATER QUALITY

2.1 General

Wastewater analyses were carried out on over 40 water plants throughout Ontario. Most of the plants were visited and sampled but several sent sludge samples to the laboratory. The physical characteristics of the wastes were evaluated to aid in determining the facilities needed to collect and treat the backwash water and clarifier/sedimentation tank sludges. The chemical and bacteriological characteristics were determined to evaluate the extent of the polluting nature of the waste and the possibilities available for sludge disposal.

2.2 Water Quality

2.2.1 Raw water quality

Table 3 outlines the water plant breakdown in terms of the number of plants and the 1973 average daily flow for the four categories of treatment plants.

The bottom half of the table outlines the raw water turbidity and colour characteristics of the two dominant categories of treatment plants.

Of the 63 turbidity removal plants the largest portion, in terms of daily flow, have an average raw water turbidity of less than 5 Formazin turbidity units (Ftu).

Of the 30 colour removal plants the largest portion, in terms of daily flow, treat water with a raw water colour in the 20 - 45 Hazen range.

The other 12 plants not listed in this table are either iron or algae removal plants. The total average daily flow of these plants was 18.7 MIGPD (85,000 m^3/day).

TABLE 3. WATER PLANT PROCESS BREAKDOWN

Process	No. of Plants	Volume MIGPD	% of Total Volume
Turbidity removal	63	617.6	84.2
Colour removal	30	96.7	13.2
Algae removal	4	11.8	1.6
Iron removal	8	6.9	1.0
Total	105	733.0	100.0

Raw Water Turbidity Breakdown

Turbidity Range (Ftu)	No. of Plants	Volume MIGPD	% of Total Volume
< 5	25	435.5	59.4
5-10	16	156.7	21.4
10-25	16	16.8	2.3
25-50	5	8.2	1.1
> 50	1	0.3	0.0

Raw Water Colour Breakdown

Colour Range (Hazen)	No. of Plants	Volume MIGPD	% of Total Volume
5-20	5	13.6	1.9
20-45	15	64.7	8.8
45-80	9	18.3	2.5
> 80	1	0.1	0.0

2.2.2 Chemicals used in water treatment plants

Table 4 lists the six main chemicals used in water treatment plants throughout Ontario, other than those used for disinfection or post filtration pH correction.

The most commonly used chemical was alum. Over 70,000 lb (31,815 kg) were used on the average per day in 1973. Carbon, added at 15 plants when needed, was applied at the rate of 3,075 lb/day (1,398 kg/day). Only seven plants used polymer on a continuous basis but four other plants used it intermittently when the raw water conditions warranted its use.

2.2.3 Raw water quality vs chemicals used

(1) Turbidity. A correlation between raw water turbidity and alum dosage was attempted from data gathered from the turbidity removal plants using the Great Lakes as the raw water source. The results are shown in Figure 1.

TABLE 4. CHEMICALS USED IN WATER TREATMENT PLANTS

Purpose	Chemical	No. of Plants	Weight lb/day
Primary Coagulant	Alum	81	70,500 $Al_2(SO_4)_3$ $(14H_2O)$
Primary Coagulant	Polymer	1	25 (dry wt)
Coagulant Aid	Activated Silica	17	1330 (SiO_2)
Coagulant Aid	Polymer	6*	50 (dry wt)
Taste & Odour Control	Carbon	15**	3075
Softening or Coagulant Aid	Lime	6	1700 ($Ca(OH)_2$)

* three additional plants also use polymer intermittently
** intermittent use

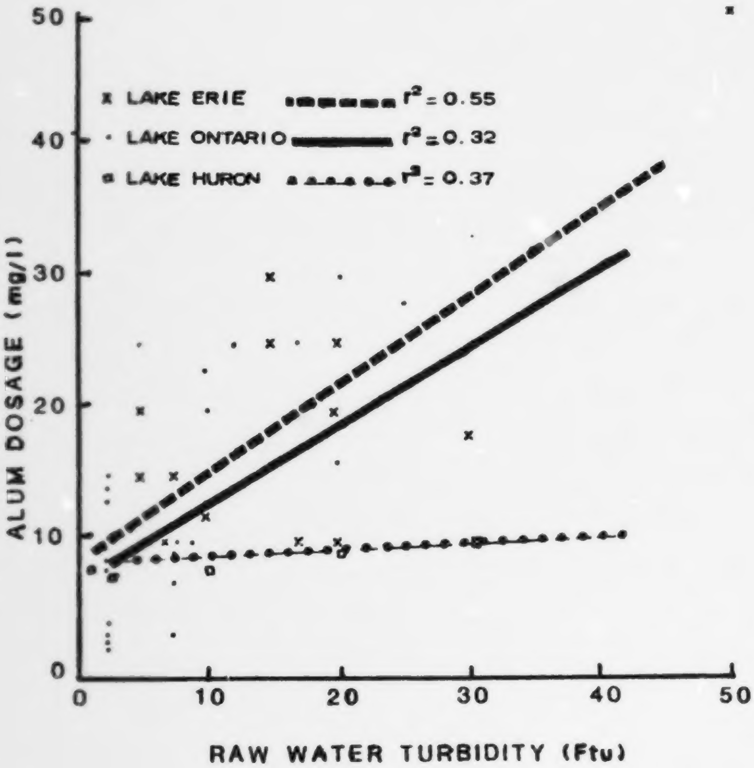

FIGURE 1. RAW WATER TURBIDITY VS ALUM DOSAGE USED FOR SEVERAL ONTARIO WATER TREATMENT PLANTS

The coefficient of determination, r^2 [6], was calculated for each source. It was used to measure the "goodness of fit" of the regression line plotted. An r^2 value of 1 indicates a perfect fit of all points on the line. The coefficients for the three lakes were only fair. The correlation between turbidity and alum dosage for the 14 Lake Erie water plants was found to be the best. The difference in the plant to plant operation was probably due to water quality differences other than turbidity (e.g. algae or pH), or physical differences in the plant facilities.

On Lake Ontario, nine plants with raw water turbidity levels in the 0 to 5 Ftu range added between 2 and 15 mg/l of alum. This is indicative of the wide range of operating methods practiced in Ontario.

(2) Colour. A relationship between alum dosage and raw water colour for 26 water plants is shown in Figure 2. Approximately 3 mg/l of alum was required for every 2 Hazen units over 15. Again the results for individual plants varied widely and the overall coefficient for determination, r^2, was 0.42.

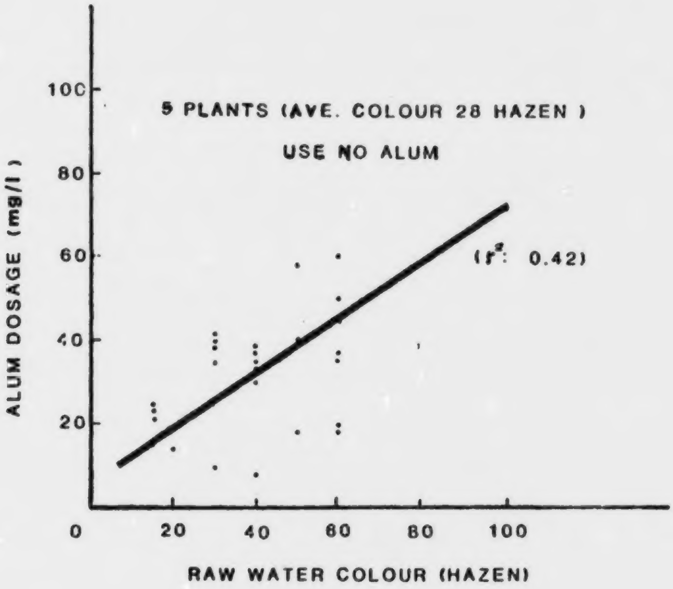

FIGURE 2. RAW WATER COLOUR VS ALUM DOSAGE USED FOR SEVERAL ONTARIO WATER TREATMENT PLANTS

The alum dosage was found to be substantially different among several plants with the same raw water colour. For example, three plants with a raw water colour of 50 Hazen used alum dosages of 18, 40 and 58 mg/l. This widespread difference was probably attributable to the raw water pH and alkalinity levels; differences in treatment facilities should be taken into account as well.

2.3 Sampling, Analysis and Results

2.3.1 Sampling procedures

2.3.1.1 Backwash effluent water. The operator was instructed to carry out the backwash of the filter in the same manner as the regular operation. Eight, 32-oz (0.9-litre) backwash water samples were taken during the course of the backwash cycle. The samples were collected more frequently during th period of peak suspended solids overflow.

The weight of solids removed from the filters was determined from a knowledge of the backwash flow rate, the time and the corresponding suspended solids levels. All samples were tested for their physical characteristics and submitted to the Ontario Ministry of the Environment, Toronto, main laboratory for chemical analysis.

Typical results of the variation of several chemical and physical parameters during the filter backwash for two plants are shown in Figure 3.

The filter in plant A was air-scoured prior to filter backwash. This accounted for the high level of solids appearing early in the cycle. The backwash of plant B was more typical of the average backwash in Ontario. The displacement of the solids immediately above the filter bed (up to 4 ft (1.2 m) of water) accounted for the low level of solids being removed in the first minute of the backwash. As the backwash rate was increased and the first surface agitators were turned on, the rate of suspended solids overflow increased until a peak was reached. During the latter half of the filter wash, the solids level gradually decreased until the wash was completed. Generally, most chemical parameters varied directly with the suspended solids levels.

2.3.1.2 Sedimentation and flocculation basins. Nineteen plants with flocculation and sedimentation facilities were sampled by COA personnel. In each case, the basin was drained first to remove all excess water.

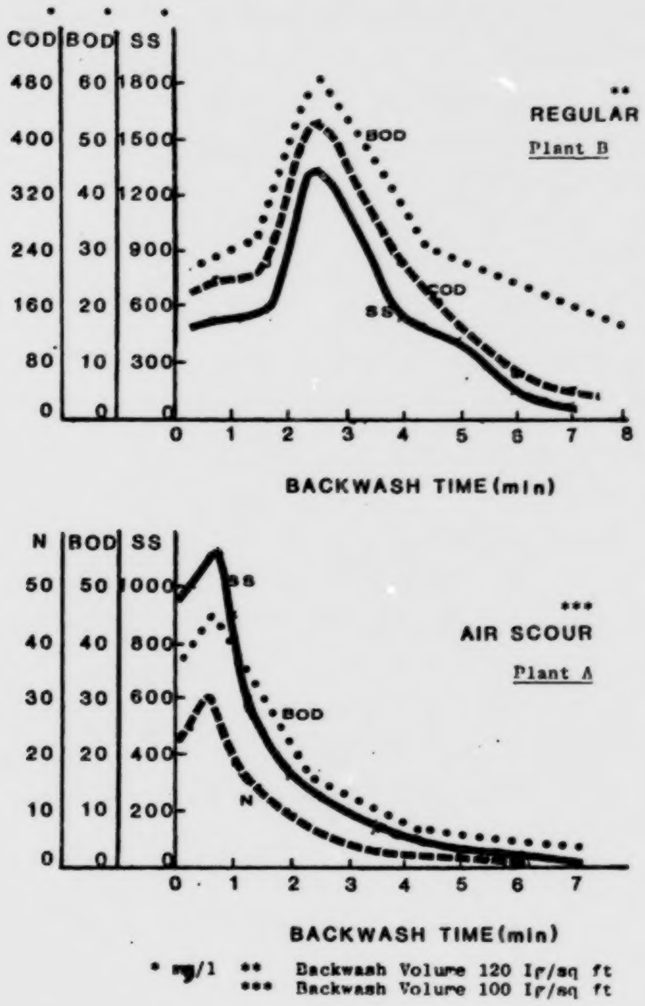

FIGURE 3. BACKWASH CURVES SHOWING PHYSICAL AND CHEMICAL CHARACTERISTICS VS TIME

The average depth of sludge in the sedimentation basins was found to range from 3 in to 3 ft (7.6 cm to 0.9 m) from plant to plant. Within a given basin, the sludge depth could vary by as much as a factor of three.

Since both the depth of sludge and the sludge concentration could vary substantially within a given basin, several samples were taken at various locations and depths within the basin.

Multiple samples from the sedimentation basin were taken at the South Peel Water Treatment Plant in Mississauga. Two samples, one in the upper and one in the lower half of the sludge, were taken at each of nine sample locations along a horizontal plane. Suspended and total solids analyses were carried out on each sample. The results of the suspended solids analyses are shown in Figure 4.

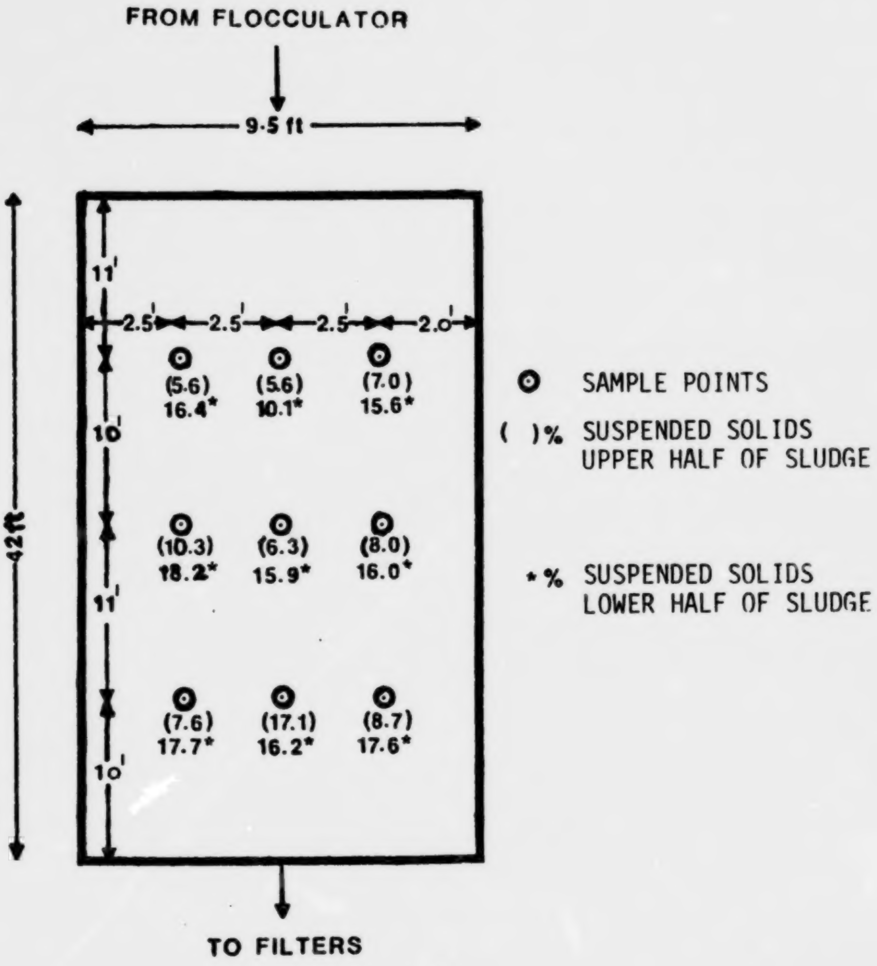
FROM FLOCCULATOR
9.5 ft
42 ft
11'
2.5'
2.5'
2.5'
2.0'
(5.6)
16.4*
(5.6)
10.1*
(7.0)
15.6*
10'
(10.3)
18.2*
(6.3)
15.9*
(8.0)
16.0*
11'
(7.6)
17.7*
(17.1)
16.2*
(8.7)
17.6*
10'
TO FILTERS
SAMPLE POINTS
( )% SUSPENDED SOLIDS UPPER HALF OF SLUDGE
*% SUSPENDED SOLIDS LOWER HALF OF SLUDGE

FIGURE 4. SUSPENDED SOLIDS CONCENTRATION OF SAMPLES TAKEN THROUGHOUT A DRAINED SEDIMENTATION BASIN

The results indicate a widespread variation between the upper and lower sludge suspended solids concentration. For most of the samples at the same depth the results were fairly consistent. Samples taken near the centre of the basin were expected to give the most representative picture of the settled wastes within the time allowable and the facilities available for analyses. If the sludge depth exceeded 6 in (15 cm), two samples were taken, one from the lower and one from the upper section of the sludge. If the sludge depth was less than 6 inches two samples were taken in the same general area near the basin floor; a composite was submitted for analysis.

2.3.1.3 Clarifier blowdown. There are 21 plants in Ontario equipped with solids contact clarifiers. Only two of the 21 plants metered their waste. These two and six other plants were sampled.

To determine the waste volumes in the other six plants, one of the following procedures was used:

1. Filling a container of known volume for a given length of time (two plants).
2. Theoretical hydraulic calculations (two plants).
3. Manufacturer's specifications (one plant).
4. Estimate based on wastewater concentration (one plant).

Blowdown practices varied from plant to plant and with the raw water quality. With the older plants a variable blowdown time once per day was common. The newer plants have devices to waste a certain amount of sludge for each unit of raw water.

At all eight plants, representative samples were collected through multiple sampling during the blowdown or by sampling the entire blowdown volume.

2.2.1.4 Microstrainer discharge. There are five water plants in Ontario that use microstrainers in the water treatment process. For three plants, this represented the only treatment apart from disinfection. The other two plants were visited and samples of the backwash from the screens were taken. Only one plant metered the wastewater. Representative samples of the wastes were difficult to obtain due to the widely varying levels of algae present in the raw water and the dependence of the microstrainers on the pumping rate of the plant.

In all cases the wastes were discharged directly back into the raw water source without any treatment.

The frequency of use of the microstrainers was for three to six months of the year for two plants and 12 months for the other three. The wastewater volume at the one plant that metered its waste was in the range of 2 percent to 4 percent of the total water flow.

2.2.2 Physical analyses

2.2.2.1 Viscosity. The literature suggests that sewage and water treatment plant sludges are mostly Bingham Plastics [5]. Fluid movement of Bingham Plastics is not initiated until a yield value of shear stress is overcome. This is an important factor if pumping the sludge is to be considered. For this reason viscosity tests were carried out on all wastewater samples. A Stormer viscometer was used. The viscosity analysis for the filter backwash sludge was carried out only on the sample containing the highest level of suspended solids.

The dependence of the viscosity on the suspended solids levels for four water plants is shown in Figure 5.

All viscosity measurements shown were performed on sedimentation tank sludge. Measurements for two sludges were done at 5°C and 24°C with significantly higher viscosities found at the lower temperature.

2.2.2.2 Density. The densities of all composite backwash water samples were determined with a 100 ml specific gravity bottle. For samples in which the suspended solids content exceeded 5 percent, a 250 ml graduated cylinder was used.

The densities of two sludges from a colour and a turbidity treatment plant were determined at various total solids levels. The sludge was filtered and dried in the laboratory to obtain a high level of solids. Volume measurements, particularly at high solids levels, were made by immersing the sludge in oil and determining the displacement. Water was not used as it was found to penetrate the sample.

The results of these tests are illustrated in Figure 6.

The Lake Ontario sludge densities range from approximately 1 g/cc (62.4 lb/ft^3) at a solids level of 6 percent to 1.56 g/cc (97 lb/ft^3)

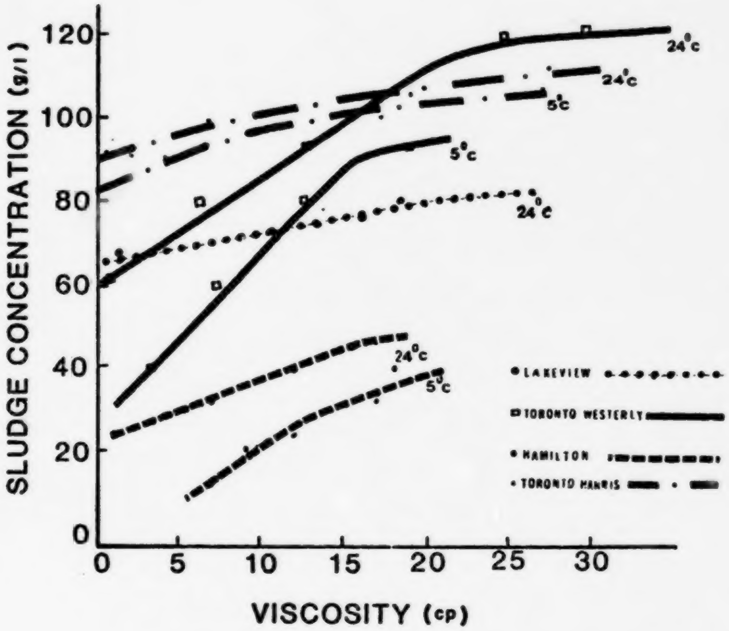

FIGURE 5. VARIATION OF SEDIMENTATION BASIN SLUDGE VISCOSITY WITH SLUDGE CONCENTRATION, TEMPERATURE AND WATER PLANT

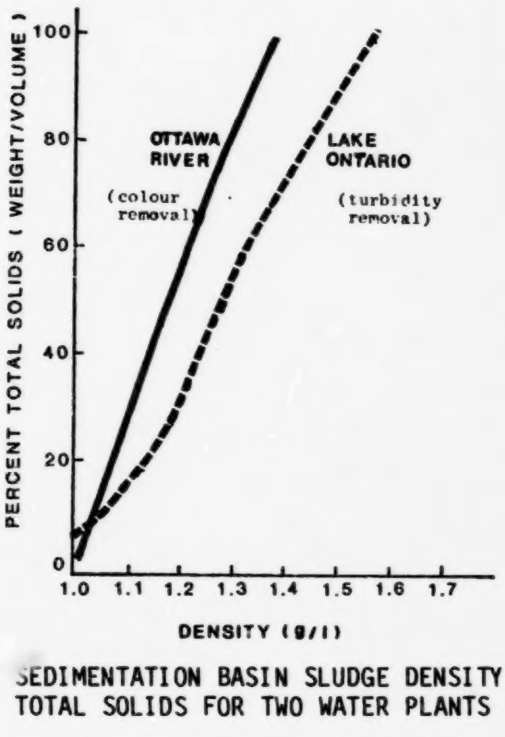

FIGURE 6. SEDIMENTATION BASIN SLUDGE DENSITY VS PERCENT TOTAL SOLIDS FOR TWO WATER PLANTS

at 100 percent solids. The Ottawa River sludge densities were slightly lower. This may have been due to the lower percentage of turbid material in the sludge.

2.3.2.3 Solids - total, suspended and total volatile. Most sludge samples collected were analyzed for total and total volatile solids. These total solids served as a basis for calculating the metal concentrations on a dry weight basis. The percentage difference between the total solids and the total volatile solids gave an indication of the organic content of the solids.

The suspended solids results were used to complete mass balances on several water plants (Wastewater Quantity 3.3). In addition, the data were used to determine the location of the waste deposition within the water plant. Suspended solids measurements were also used to determine two important relationships: suspended solids vs turbidity and suspended solids vs alum addition.

Guiver stated that the Royal Commission on sewage disposal set 30 mg/l as the maximum limit for discharge of suspended solids [1]. Any further increase in the turbidity of water or blanketing of the river bed was undesirable as reduced growth of aquatic vegetation was possible.

(i) Suspended solids vs turbidity. A relationship between the suspended solids and the raw water turbidity was developed for several plants on the Great Lakes. This relationship is outlined in Figure 7. Included in this figure is the correlation of data collected from 21 grab samples taken at the time of the sampling program. The coefficient of determination [6], r^2, was calculated for all plants as well as for the 21 grab samples. The data fitted the regression line well with r^2 values ranging from 0.75 to 1.00.

Several inland rivers and areas on the Great Lakes known for significant algae levels (over 100 Asu/ml) were tested separately. Suspended solids/turbidity ratios for these locations ranged from 2:1 up to 5:1 during periods of high algae loadings.

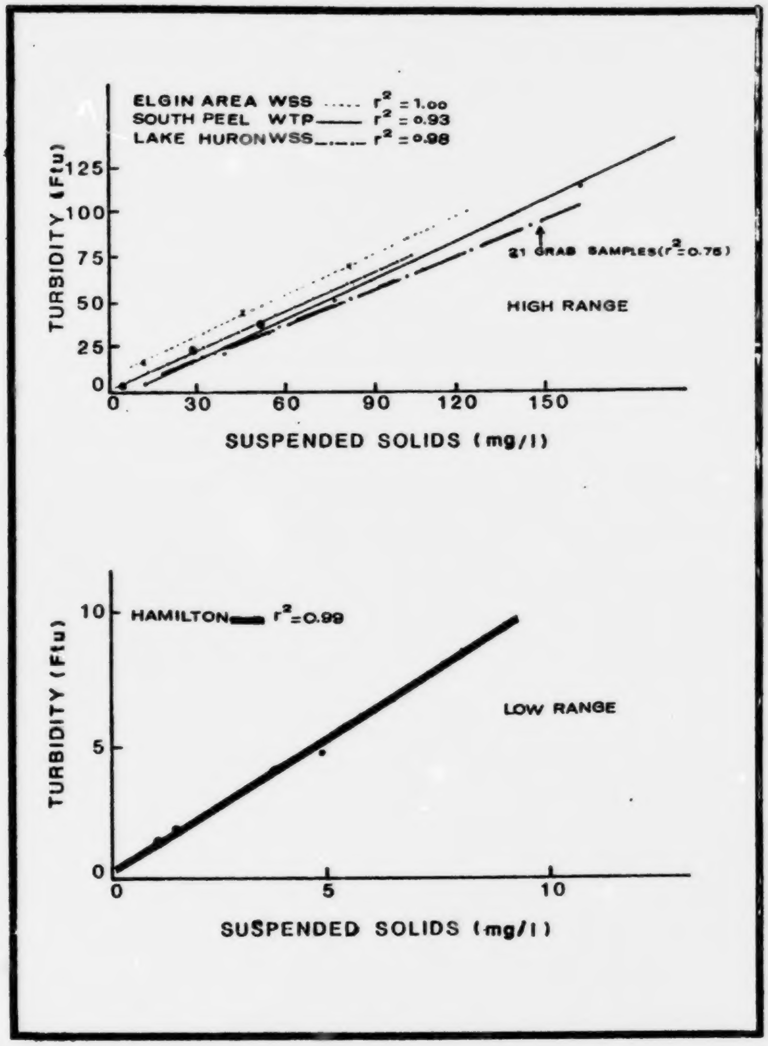

FIGURE 7. RELATIONSHIP BETWEEN RAW WATER TURBIDITY AND SUSPENDED SOLIDS FOR SEVERAL LOCATIONS THROUGHOUT ONTARIO

(ii) Suspended solids vs alum dosage. A raw water sample was taken at most water plants that were visited in Ontario. Commercial alum was added to the sample in the laboratory at a dosage approximating that of the plant at the time of the visit. All dosages were carried out at room temperature and the pH was noted. The sample was flocculated for 30 minutes with a velocity gradient of 20 sec^{-1}. Suspended solids were then determined on the raw and the flocculated water. The results from 15 plants are given in Figure 8. The ratio developed for most plants of alum dosage (mg/l) to suspended solids (mg/l) was 1:0.4. There was some fluctuation of the ratio values at different pH levels and between hard and soft waters.

An alum/suspended solids ratio of 1:0.4 was used for determining the suspended solids loadings in most plants. For those plants where the flocculation pH was near 6.0, a 1:0.45 ratio was used. At pH values near 8, an alum/suspended solids ratio of 1:0.3 was used.

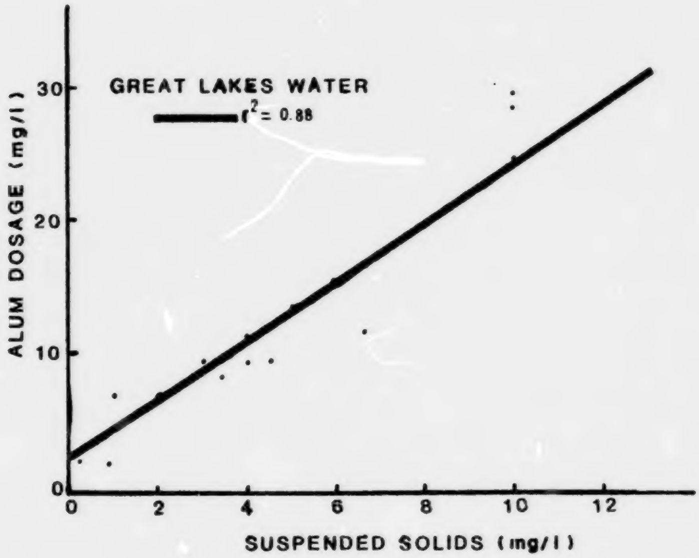

FIGURE 8. ALUM DOSAGE OF GREAT LAKES WATER VS INCREASE IN SUSPENDED SOLIDS.

2.3.2.4 Settling time.

(i) Theory. Sedimentation removes suspended solids from water by:

1) Clarification - to produce an effluent free of settleable solids.
2) Thickening - to produce an underflow which contains solids in a concentrated form.

Sedimentation data was collected to determine both the area and volume required for clarification as well as the area and volume required for thickening.

The theory of sedimentation has been discussed at length by many authors [7].

O'Brien and Gere give practical examples of sizing sedimentation and collecting facilities based on bench and pilot plant tests [8].

(ii) Equipment. All sedimentation tests were carried out at 24^{o}C using a standard 250 ml graduated cylinder; the sample was thoroughly mixed prior to adding it to the cylinder. The height of the interface was noted with respect to time. The sample was considered to be settled when the floc level was below 10 percent of the total depth. The height of the cylinder was 25 cm.

Akers commented on the restrictions of using small settling chambers for sedimentation tests [7]. He noted several factors that would contribute to erroneous results. These included wall effects, hydrodynamic interaction between particles, the displacement flow of the liquor and the limitation of fluid flow through the agglomerating floc particles.

Bauman has suggested that an acrylic column, at least 1.5 m high and 0.15 m in diameter be used to minimize the errors [7]. This was impractical for most of our work due to time and distance limitations but several tests were carried out on selected samples in a 1.8 m high column.

Comparative settling tests between a 250 ml graduated cylinder and a 1.8 x 0.15 m column were run on three different backwash samples. Two backwash water samples were collected from turbidity removal plants and one was collected from a colour removal plant.

The results showed that when the 250 ml graduated cylinder settling test using water collected from a turbidity removal plant was considered to be complete, 15 - 20 percent of the suspended solids were above the 0.15 m mark in the 1.8 m column. When water collected from a colour removal plant was felt to be settled in the 250 ml cylinder, 40 percent of the suspended solids were above the 0.15 m mark in the 1.8 m column. This percentage should be noted when reviewing the laboratory results for the other plants in the Province when bench scale tests have been used.

(iii) Filter backwash settling curves. Two settling tests were carried out on the backwash water taken from a Lake Ontario plant. One test was performed at 5°C and the other at 24°C to investigate temperature effects on settling characteristics. The initial suspended solids concentration of the water was 630 mg/l. Samples were drawn off at the 0.15, 0.8 and 1.2 m sampling ports; 1.8 m of liquid was used.

The samples were withdrawn periodically from all three sampling ports and a suspended solids analysis was carried out on each. Tests were run in this manner to determine if it was possible to decant a certain proportion of supernatant back into the receiving stream at any given time and to treat or to dispose of the residual liquid separately.

The results are shown in Figure 9. The percentage of suspended solids below the three sampling ports at various time intervals up to 70 minutes is shown.

As can be seen in Figure 9, after 30 minutes of quiescent settling at 24°C, the suspended solids below the 0.15 m, 0.8 m and 1.2 m levels were 82 percent, 89 percent and 93 percent of the total SS, respectively. In contrast to this, at 5°C, the suspended solids below the same three ports were 69 percent, 79 percent and 87 percent, respectively of the total suspended solids in the column. These results indicate the importance of temperature in the design and operation of any holding tank if discharge of the supernatant is contemplated.

Figure 10 outlines the suspended solids concentration above the 0.15 m sampling port over a period of time. The backwash water used in this test was the same as that discussed regarding Figure 9.

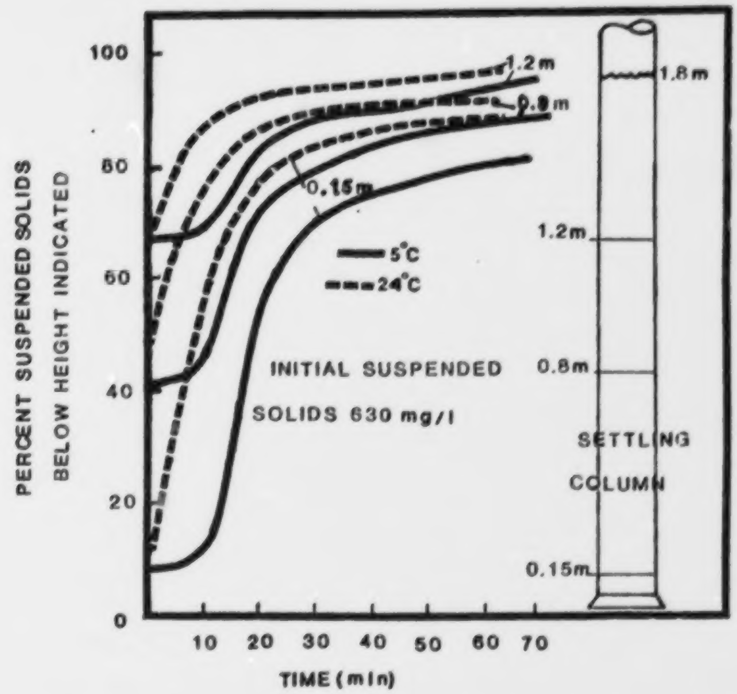

FIGURE 9. SETTLING TEST OF BACKWASH WATER IN A 1.8 m COLUMN

After 30 minutes of settling at 24^{o}C, the suspended solids concentration of the liquid above the 0.15 m point was approximately 100 mg/l; at 5^{o}C, this concentration was 200 mg/l. The suspended solids concentration at 24^{o}C did not change significantly in the next 40 minutes of settling while the suspended solids at 5^{o}C dropped slightly.

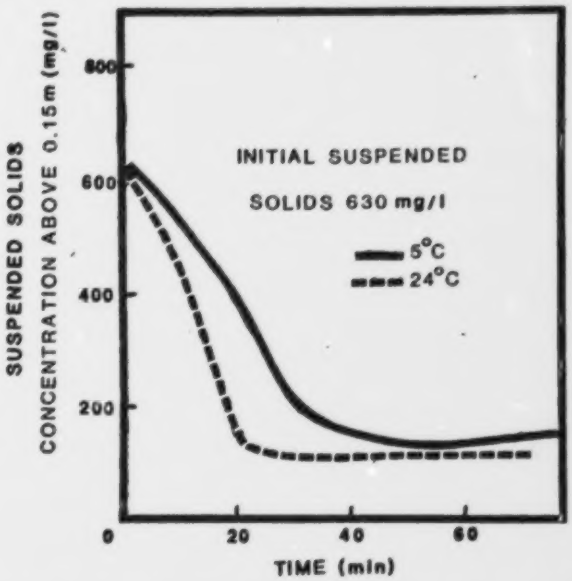

FIGURE 10. SETTLING TEST OF BACKWASH WATER IN A 1.8 m COLUMN; SUSPENDED SOLIDS LEVEL ABOVE 0.15 M VS TIME

Figure 11 outlines the settling characteristics of three different backwash water samples. Two samples were taken from Lake Ontario (turbidity removal) and one from the Ottawa River (colour removal) water plants. Both the percentage of suspended solids below the 0.15 m mark and the suspended solids of the supernatant above 0.15 m are shown.

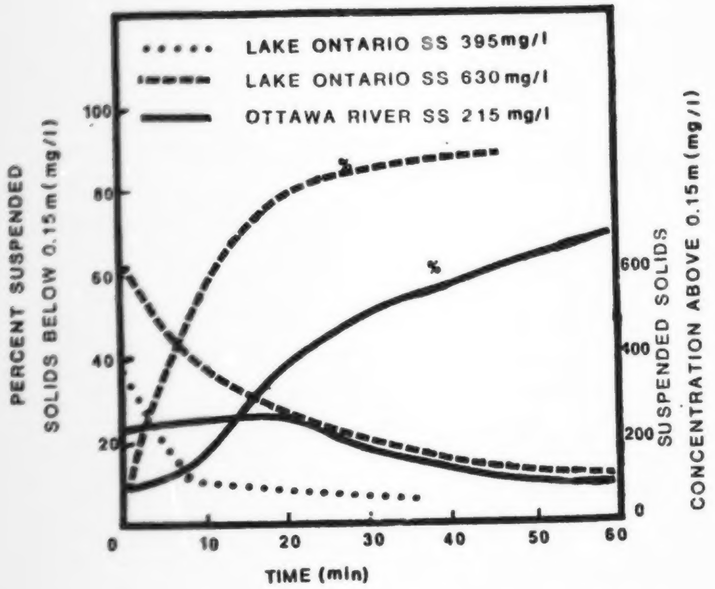

FIGURE 11. SETTLING TEST OF THREE BACKWASH WATERS IN A 1.8 m COLUMN

The initial suspended solids of the backwash waters were 395 mg/l and 630 mg/l for the Lake Ontario water and 215 mg/l for the Ottawa River water. The analyses showed that the solids in the Ottawa River wastewater (coloured) settled slower than the solids in the Lake Ontario wastewater (turbid), with the overall result that a lower percentage of the total suspended solids is removed over the measured period of time. The two Lake Ontario backwash waters had substantially different supernatant suspended solids levels throughout the run. The sample with the initial suspended solids level of 630 mg/l had a supernatant suspended solids level above the 0.15 m depth of two to three times that of the backwash water with the initial suspended solids level of 395 mg/l.

The solids in both the coloured water and the lower turbidity water samples were collected and allowed to settle for 20 hours. The suspended solids of the supernatant above the 0.15 m level dropped in a manner shown below:

Time (hr)	0	1	2	5	20
Turbid Backwash (SS)	395	46	25	11	8
Coloured Backwash (SS)	215	102	-	-	75

The above table indicates that sedimentation of coloured backwash water resulted in the reduction of the suspended solids in the supernatant by 65 percent after 20 hours of quiescent settling. A 98 percent suspended solids reduction for the turbidity removal plant backwash water was found after the same 20 hour settling period.

2.3.2.5 Results and discussion. The results of the physical analyses carried out on the sedimentation and backwash water samples are given in Table 5.

The viscosity of the backwash water samples was below 2 centipoise in all cases. The average concentration of suspended solids found for the backwash water was in the 0.5 to 1.0 g/l range. The settling time in the 250 mg/l graduated cylinder at 24°C was in the 19 to 28 minute range.

The sedimentation basin samples had widely varying viscosity levels which were dependent on the solids content of the sample. The highest density was 1.1 g/cm^3 with the average in the range of 1.02 to 1.05 g/cm^3. The settling times were about 50 percent longer than those of the backwash water. Suspended solids levels were found to be as high as 181 g/l; the average was generally in the 5 - 10 g/l range for the water plants excluding those plants on Lake Ontario where the average was determined at approximately 55 g/l.

2.3.3 Chemical analyses - Part 1

2.3.3.1 Biochemical oxygen demand (BOD_5). The BOD_5 test is defined as the measure of dissolved oxygen required for the aerobic bacterial stabilization of decomposable organic matter in a five day period at 20°C in the absence of light [9].

The BOD_5 tests were carried out at the main Ministry of the Environment (MOE) laboratory to assess the extent to which water plant wastes may deplete the dissolved oxygen levels of the receiving stream. This oxygen depletion arises through bacterial oxidation of the organic material.

TABLE 5. WASTEWATER PHYSICAL ANALYSES

Waterway	Viscosity* Centipoise Ave.-Max.	Density g/cm^3 Ave. Max.	Settling Time (min.) Ave.-Max.	Suspended Solids g/l Ave.-Max.
Lake Ontario				
BW (9)	1.2-1.6	1.006-1.02	20-30	0.5-1.0
Sed (8)	1.6-96**	1.05-1.1	29-50	55-181
Lake Huron thru Lake Erie				
BW (9)	1.5-1.6	1.00-1.00	19-30	1.04-4.3
Sed (7)	3.6→96**	1.03-1.08	23-40	5-136
Rivers including Ottawa River				
BW (8)	1.2-1.5	1.00-1.00	28-35	0.85-2.0
Sed (7)	2.1-5.0	1.02-1.05	39-60	10.4-40

Where BW = Backwash wastes
Sed = Sedimentation tank or clarifier wastes
( ) = Number of results available
* = BW viscosity performed on BW sample with the highest suspended solids
** = Excludes very high results from dense sludges

Guiver indicated that depletion of the dissolved oxygen content of a river water below 2 mg/l can increase the toxic effects of certain chemicals [1]. The maximum BOD_5 level for most wastewater plant effluents is generally recommended to be less than 20 mg/l and is determined by an assessment of the assimilative capacity of the receiving stream.

Chemical oxygen demand (COD). The chemical oxygen demand is a measure of the oxygen required to oxidize susceptible organic compounds under vigorous chemical oxidizing conditions [9].

The COD analyses on all wastes were carried out at the MOE main laboratory to assess the ultimate chemical oxygen demand that may eventually be exerted on the receiving stream.

2.3.3.2 pH. The hydrogen ion concentration in water is recorded as pH. Because pH is a perishable parameter, the pH measurements listed in the results should not be regarded as representative of the pH at the time of sampling. They should thus be interpreted as "pH-at-the-lab". All pH levels were determined by COA personnel using a Fischer Model 220 pH meter.

Sulphates. Sulphate levels in most natural waters vary between 10 and 80 mg/l.

Wastewater concentrations were determined spectrophotometrically at the MOE laboratory from comparison with those of the receiving waters.

2.3.3.3 Total Kjeldahl nitrogen. The total Kjeldahl nitrogen is a measure of all the nitrogen in the trivalent state. This includes nitrogen present as free ammonia as well as that found in the organic state as in proteins, amines etc. It does not include nitrogen present as nitrite or nitrate. Kjeldahl nitrogen is used as an indication of sanitary water quality.

All nitrogen sample analyses were carried out at the MOE laboratory by digestion followed by colorimetric measurement.

Nitrate nitrogen. Nitrates are formed through the oxidation of nitrite by autotrophic nitrifying bacteria. They are the most highly oxidized form of nitrogen in the nitrogen cycle.

Nitrates are generally found in trace concentrations in all surface waters. Their presence is undesirable because their nutritive properties can promote excessive growth of algae and other aquatic plants.

Total phosphorus. Phosphorus occurs in natural and wastewaters in several different combinations. All of the various compounds may eventually be used in metabolic biological processes but the rate at which each form is used is in question.

The percentage of the plant-available phosphorus in the total phosphate analyses is not known.

2.3.3.4 Results. The results are listed in Tables 6 through 8. The findings are listed under the following headings:

(i) Lake Ontario and St. Lawrence River
(ii) St. Clair River, Lake Erie to Niagara Falls
(iii) Lake Huron

(iv) Ottawa River

(v) Inland Rivers

(vi) Microstrainer, Iron Removal and Softening Wastes

For most of the plants in each section, the raw water source is the same as the waste deposition water; exceptions to this are marked.

In several cases duplicate samples were taken six months apart and are appropriately indicated.

(i) Lake Ontario and St. Lawrence River. The results for Lake Ontario water treatment plants are shown in Table 6. The pH of the wastes was in the 6.6 to 8.1 range. The BOD_5 concentrations for most of the backwash waters were well below 15 mg/l. The sedimentation basin sludge had BOD_5 concentrations of up to 1900 mg/l. There was a general relationship between the BOD_5, COD and the suspended solids levels.

Total Kjeldahl nitrogen varied widely from a low of 0.7 mg/l for the Ajax sedimentation sludge to a high of 1200 mg/l at the Toronto Westerly plant. Phosphate levels also varied widely depending on the location of the wastes. Nitrate levels did not exceed 0.6 mg/l in any samples. Sulphate levels were in the 20 to 44 mg/l range.

(ii) St. Clair River, Lake Erie and Niagara Falls. As shown in Table 7, the backwash water quality was similar to that found in the other lakes. The sedimentation sludge at the Elgin Area WSS had the highest BOD_5 level of any plant sampled throughout the Province. The clarifier blowdowns had considerably lower suspended solids, BOD_5 and COD levels than did the sedimentation basin wastes.

The maximum Kjeldahl nitrogen and phosphorus levels found were 170 and 70 mg/l, respectively, both well below that found in Lake Ontario. Nitrate levels were 1 mg/l or less with most samples being below 0.2 mg/l. Sulphate levels were in the 25 to 32 mg/l range.

(iii) Lake Huron. Table 7 lists also results from water treatment plants on Lake Huron. The plants of significant size on Lake Huron, specifically the Lake Huron WSS, Lambton Area WSS and the Owen Sound plant, are all direct filtration plants. Therefore, the only waste material is that of the backwash water (Table 7).

TABLE 6. WASTEWATER CHEMICAL ANALYSES - PART 1, LAKE ONTARIO AND ST. LAWRENCE RIVER

Plant Location	Waste Type	Solids Total g/l	Solids Susp. g/l	Solids Total Vol. g/l	pH	BOD_5 mg/l	COD mg/l	Total Kjeldahl Nitrogen as N mg/l	Total Phosphate as P mg/l	Total Nitrate as NO_3 mg/l	Total Sulphate as SO_4 mg/l
Grimsby	BW	-	0.03	-	7.3	3	35	-	0.1	< 0.2	35
	Sed.	16.6	12.3	2.1	8.1	120	-	80	3	< 0.2	34
St. Catherines	BW	-	0.35	-	7.6	20	100	-	1.0	0.4	40
	Sed.	-	55	-	-	1,400	9,000	-	90	< 0.2	-
Hamilton**	BW	-	0.2	-	7.1	6	100	4.5	1	< 0.2	36
	Sed.	156	146	37	6.7	160	7,000	15	4	-	-
	Sed.	77.5	56	18.5	6.9	800	-	550	140	< 0.2	-
South Peel	BW	0.53	0.33	-	7.2	25	120	7.5	1.1	0.2	31
	BW	0.84	0.63	-	7.8	6.5	50	2.6	0.8	0.4	44
	Sed.	91	79	10	6.9	360	5,900	250	19	-	-
	Sed.	123	117	14	6.8	1,100	-	500	130	< 0.2	-
Toronto - Island	BW	0.25	0.03	-	7.6	3	< 20	-	0.1	0.2	31
- Harris	BW	0.42	0.11	0.09	7.3	5	50	3	0.3	0.2	35
	Sed.	158	154	26	6.9	900	6,800	600	180	0.2	-
- Westerly	BW	0.4	0.25	-	7.5	3	50	3.5	1.1	0.2	31
	Sed.	87	73	17	7.4	1,250	12,500	-	-	0.2	-
	Sed.	171	162	41	7.3	1,400	12,000	1,200*	300	< 0.2	-
Ajax	Sed.	-	180	-	6.9	1,400	17,000	0.7	0.3	0.6	-
Oshawa	Sed.	270	218	30	6.7	1,900	27,000	1,000	260	< 0.2	-
Bowmanville	BW	0.33	0.30	-	7.5	1.2	-	0.6	0.3	< 0.2	36
Belleville	BW	0.7	0.27	0.4	6.6	3	130	-	0.8	< 0.2	26
Kingston	BW	0.3	0.1	0.08	7.3	3	30	-	0.2	0.2	32
	Sed.	21	20	11.3	6.7	600	-	600	100	0.2	20
Cornwall	BW	-	0.2	-	7.8	4	60	3.5	1.3	0.6	31
	Sed.	71	71	-	7.4	500	15,000	-	-	0.2	-

* Free Ammonia as N - 40 mg/l
** Discharge to Hamilton Bay

Sed. = Sedimentation Basin Sludge
BW = Backwash Water

TABLE 7. WASTEWATER CHEMICAL ANALYSES - PART 1, ST. CLAIR RIVER AND LAKE HURON

Plant Location	Waste Type	Solids Total g/l	Solids Susp. g/l	Solids Total Vol. g/l	pH	BOD_5 mg/l	COD mg/l	Total Kjeldahl Nitrogen as N mg/l	Total Phosphate as P mg/l	Total Nitrate as NO_3 mg/l	Total Sulphate as SO_4 mg/l
				St. Clair R., Lake Erie to Niagara Falls							
Windsor	BW	-	0.45	-	7.5	5	120	-	1.2	< 0.2	20
	Sed.	34	34	5	6.9	240	4,200	170	1.0	< 0.2	-
Amerherstburg	BW	-	0.01	-	7.5	1	< 20	-	0.1	< 0.2	25
	C	-	4.1	-	7.2	13	580	-	7.6	< 0.2	-
	C	7.6	7.4	1.1	-	160	700	26	6.0	1.0	32
Union WSS	BW	0.24	0.06	0.14	7.3	1.2	35	-	0.1	< 0.2	29
	C	3.4	3.4	0.8	7.5	17	580	21	7.2	< 0.2	-
	C	1.03	0.8	0.25	-	19	150	5	1.4	0.4	32
Blenheim	BW	-	0.06	-	7.3	0.4	70	-	0.1	< 0.2	-
	C	-	2.7	-	7.0	6.0	460	-	4	< 0.2	-
Elgin Area WSS	BW	-	0.15	-	7.9	3	35	3	0.5	< 0.2	-
	Sed.	106	102	8	7.0	6,000	9,200	-	70	< 0.2	-
Niagara Falls	BW	-	0.25	-	7.6	12	85	-	0.9	< 0.2	30
	Sed.	64	62	11	-	3,500	14,000	-	-	< 0.2	-
					Lake Huron						
Thornbury*	BW	-	1.2	-	7.5	5	120	-	1.2	< 0.2	20
	C	2.1	1.9	0.4	6.9	240	4,200	170	1.0	< 0.2	-
Owen Sound	BW	-	0.15	-	7.7	2	45	-	0.3	< 0.2	25
Goderich	Bw	0.43	0.22	0.11	7.6	8	-	-	-	-	-
	Sed.	-	136	-	7.4	-	-	6.5	15.7	-	-
Lake Huron WSS	BW	-	0.14	-	7.4	18	100	-	0.6	< 0.2	-
	BW	0.9	0.6	0.06	-	10	60	-	0.6	< 0.2	-

* Source - Beaver River

C = Clarifier

BW = Backwash Water

I = Iron Backwash

S = Softening Wastes

Sed. = Sedimentation Basin Waste

Micro = Microstrainer Discharge

(iv) Ottawa River. As indicated in Table 8, the pH of the wastewater leaving the water treatment plants on the Ottawa River was lower than that found for wastewaters being discharged from water plants on other waterways. Kjeldahl nitrogen values for the sedimentation sludges varied widely from 32 to 600 mg/l. The free ammonia content of the sludge samples, varying in Kjeldahl nitrogen content between 6.9 and 95 mg/l, had free ammonia levels of about 0.4 mg/l.

(v) Inland rivers. Table 8 shows that the highest BOD_5 level in the five water plants on inland rivers sampled was 60 mg/l for the sedimentation tank sludge at the Perth WTP. A higher COD/BOD_5 ratio was found for these plants than in the plant waste discharging to the Great Lakes. Total Kjeldahl nitrogen levels varied from 1.7 to 10 mg/l. The phosphate level of the Perth WTP sedimentation basin sludge was well above that of any of the other sludges but the solids level was also much higher.

Brantford WTP recorded the highest nitrate levels found, at 3.0 mg/l, for both the backwash water and the sedimentation basin blowdown. The sedimentation blowdown was the diluted waste as it entered the lagoon. Brantford surface water waste also had the highest sulphate level at 110 mg/l.

(vi) Microstrainers, iron removal and softening wastes. As stated earlier, the quality of the microstrainer wastes was highly dependent on the algae loadings and the wash water required to remove the algae matter.

The samples tested exhibited very different BOD_5 levels although the solids concentrations were not widely different.

The iron removal plants had relatively low suspended solids levels in their backwash water. The BOD_5, Kjeldahl nitrogen, phosphorus and nitrate levels were similar to those in the water works waste from plants on the Great Lakes, while the COD levels were lower. The sulphate concentration varied markedly.

Except for the higher pH values of 8.3 to 8.9, the partial softening waste characteristics studied were similar to other plants.

Table 9 presents the results of the analyses carried out on microstrainer discharge, backwash water from iron removal plants and the wastewater leaving the two partial softening plants in Ontario.

TABLE 8. WASTEWATER CHEMICAL ANALYSES - PART 1, OTTAWA RIVER AREA, INLAND RIVERS

Plant Location	Waste Type	Solids Total g/l	Solids Susp. g/l	Solids Total Vol. g/l	pH	BOD$_5$ mg/l	COD mg/l	Total Kjeldahl Nitrogen as N mg/l	Total Phosphate as P mg/l	Total Nitrate as NO$_3$ mg/l	Total Sulphate as SO$_4$ mg/l
Ottawa River Area											
Haileybury	BW	-	0.5	-	6.0	8	255	3.5	0.4	-	-
	Sed.	6.2	5.5	-	5.7	6	2,450	32	44	-	-
Deep River	BW	-	0.3	-	6	1	190	4.4	0.3	< 0.2	25
	Sed.	-	15	-	6.8	280	10,250	600	-	< 0.2	-
Ottawa - Lemieux	BW	0.26	0.24	0.12	6.0	7	120	-	0.6	0.2	34
	Sed.	-	40	-	6.4	-	2,600	-	-	< 0.2	-
	Sed.	11.8	11.4	5.7	5.8	10	3,900	95*	7.0	0.2	20
- Britannia	Sed.	10.7	10.2	5.2	6.0	8	3,500	69*	8.0	0.2	33
Rockland	Bw	-	0.2	-	6.0	7	-	-	0.3	< 0.2	-
	Sed.	1.65	1.3	-	5.9	6	600	11	1.5	-	-
	Sed.	1.29	1.0	0.45	6.7	8	410	6.9*	1.0	0.2	39
Inland Rivers											
Lindsay	BW	-	0.2	-	7.7	15	130	5.7	0.7	-	35
	C	1.5	1.3	0.6	-	11	330	-	5.2	-	-
	BW	0.78	0.15	0.19	7.7	3	30	2.5	0.5	3.0	110
Brantford	BW	-	0.2	-	7.8	2	50	-	0.2	1.2	100
	Sed.	0.9	0.25	0.27	7.6	3.5	40	2.5	1.3	3.0	110
Perth	BW	-	0.09	-	7.3	1	40	1.7	0.1	< 0.2	26
	Sed.	-	8.1	-	6.7	60	3,700	14	125	< 0.2	-
Timmins	BW	-	0.3	-	6.1	5	-	-	0.2	< 0.2	28
Sudbury	BW	-	0.06	-	6.4	6	44	0.9	0.1	-	-
	C	2.1	1.4	-	7.2	3	540	10	1.2	-	-

* Free Ammonia 0.4 mg/l

C = Clarifier
BW = Backwash Water
I = Iron Backwash
S = Softening Wastes
Sed. = Sedimentation Basin Waste
Micro = Microstrainer Discharge

TABLE 9. WASTEWATER CHEMICAL ANALYSES - PART 1

Plant Location	Waste Type	Solids			pH	BOD_5	COD	Total Kjeldahl Nitrogen as N	Total Phosphate as P	Total Nitrate as NO_3	Total Sulphate as SO_4
		Total g/l	Susp. g/l	Total Vol. g/l		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Microstrainer Waste											
Union WSS	Micro	0.9	0.6	0.16	7.5	8	160	-	-	-	-
Belleville	Micro	0.6	0.45	-	-	80	360	22	2.4	0.2	-
Iron Removal Backwash											
St. Jacobs	I	1.2	0.06	-	7.4	2	<20	-	0.4	< 0.2	600
Markham	I	0.7	0.07	-	7.9	12	<20	1.0	-	0.6	68
Richmond Hill	I	0.33	0.25	0.09	7.4	9	<20	0.3	0.8	-	120
Partial Softening Plant Wastes											
Cochrane	BW	-	0.17	-	8.3	2	<20	-	0.1	< 0.2	14
	C	8	6.6	-	8.9	6	30	0.5	0.5	-	-
Dresden	C	10.6	9.6	4.0	8.6	8	170	1.5	0.8	-	-
	C	5.9	5.6	0.3	8.3	13	110	4.0*	0.6	3.4	94

*Free Ammonia < 0.1 mg/l

C = Clarifier Waste
BW = Backwash Water
I = Iron Backwash
Micro = Microstrainer Discharge

2.3.4 Chemical analyses - Part 2

2.3.4.1 Aluminum, arsenic and lead

Aluminum. The major source of aluminum in water treatment plant waste is the alum used in the treatment process. Toxic effects on plants have been reported at extremely high or low pH levels, but at a neutral pH, toxicity effects are negligible. Acute mortalities of rainbow trout have been reported at dissolved aluminum levels of 5.2 mg/l [1].

Mortality rates for suspended aluminum at 5.2 mg/l at pH 7, 0.52 mg/l at pH 7, and 5.2 mg/l at pH 8 were all similar, indicating that toxic effects occur at lower concentrations of suspended aluminum than of dissolved aluminum. The concentration dependency of suspended aluminum toxicity is of very low order while soluble aluminum toxicities are strongly concentration dependent [3].

Depending on the level of aluminum present, the MOE laboratory carried out aluminum analyses by atomic absorption spectrophotometry or by the colorimetric aluminum method.

Arsenic. Arsenic may occur in most waters from industrial discharges, insecticide runoff or by the dissolution of any one of a number of minerals. Its presence in wastewaters may be of importance because of its high toxicity for all forms of animal life.

The Ontario Ministry of the Environment Permissible Water Quality Criteria for the Protection of Fish, other Aquatic Life and Wildlife states that, for arsenic, the environmental level of 0.01 mg/l should not be exceeded under any circumstances [10]. All sample analyses were carried out at the MOE laboratory.

Lead. Lead may occur in water plant waste discharges if the source water is near an industrial or smelter discharge point. Dissolution of lead from the lead plumbing within the water plant may also be a possible source.

The Ministry laboratory analyzed all samples by first digesting them and then using atomic absorption spectrophotometry.

2.3.4.2 Results. The analytical results on wastewater samples taken from 24 water plants throughout the Province are given in Table 10.

The sedimentation basin metal concentration, given in mg/l, is that concentration found in the sedimentation basin sludge after the basin was drained, unless otherwise indicated. It is not the level found in the liquid waste as it was discharged into the receiving stream. The wash water volume used to flush out the sedimentation basin sludge was not recorded or known at any plant visited. However, the sludge was usually diluted to a level similar to that of a heavy clarifier blowdown (around 1 percent total solids).

As Table 10 shows, alum concentrations in the sludge reached 3,100 mg/l. The dry weight concentration is given to facilitate

TABLE 10. WASTEWATER CHEMICAL ANALYSES - PART 2

Plant	Waste Type	Total Solids mg/l	Metals mg/l			Metals g/g dry weight		
			Al	As	Pb	Al	As	Pb
Grimsby	Sed.	16,620	-	0.05	0.87	-	3	52
Hamilton	Sed.	146,000	2,400	0.05	1.7	16,400	< 1	12
Hamilton	Sed.	75,500						
South Peel	Sed.	123,000	3,100	2.6	1.6	25,200	21	130
Toronto								
- Island	BW	250	0.7	0.01	0.01	2,800	40	40
- R.C. Harris	BW	420	3.0	< 0.01	0.05	7,100	<24	119
- R.C. Harris	Sed.	158,000	3,100	270	24.0	19,620	17	151
- Westerly	BW	400	10	< 0.02	0.02	25,000	<50	50
- Westerly	Sed.	171,000	230	0.24	5.2	1,345	1	30
Belleville	Sed.	9,300	940	< 0.01	0.7	101,000	< 1	75
Kingston	BW	300	-	0.01	0.02	-	33	67
Kingston	Sed.	21,000	-	0.03	2.2	-	1	105
Cornwall	Sed.	71,000	1,400	0.26	7.9	19,700	4	111
Windsor	Sed.	34,000	820	0.1	2.1	24,100	3	62
Amherstburg	C	7,760	150	0.05	0.26	19,300	6	34
Union WSS	C	1,025	72	0.4	0.06	70,200	390	59
Union WSS	C	3,400	380	0.07	0.18	111,800	21	53
St. Thomas	Sed.	106,000	2,300	< 0.01	0.14	21,700	< 0 .1	1
Niagara Falls	Sed.	64,000	1,400	0.2	3.4	21,900	3	53
Haileybury	Sed.	6,200	500	< 0.01	0.5	80,600	< 2	81
Ottawa								
- Lemieux	BW	260	-	< 0.01	0.02	-	<38	77
- Lemieux	Sed.	11,830	8.0	0.31	0.7	680	26	59
- Britannia	Sed.	10,740	122	0.265	1.2	11,350	25	112
Rockland	C	1,650	160	< 0.01	0.12	97,000	< 6	73
Rockland	C	1,300	59	0.08	0.13	45,400	62	100
Thornbury	C	2,100	93	0.01	0.07	44,000	5	33
Lindsay	C	1,500	150	< 0.01	0.06	100,000	< 7	40
Sudbury	C	2,100	220	< 0.01	0.2	105,000	< 5	95
Cochrane	C	8,000	11	0.01	0.04	1,400	1	5
Dresden	C	9,650	40	< 0.01	0.3	4,145	< 1	31
Brantford	BW	780	11	< 0.01	0.04	14,100	<13	51
Brantford	Sed.	900	1.9	< 0.01	< 0.03	2,100	<11	33

Sed = Sedimentation Tank BW = Backwash C = Clarifier comparison between all types of sludges. The highest dry weight concentration was 111,800 μg/g dry weight. Generally speaking, the metal concentrations found in the sedimentation clarifier wastes were about 100 - 200 times those in the backwash water. On a dry weight basis, the arsenic and lead levels for all three types of wastes were similar while the aluminum level of the clarifier wastes was about twice that of the other two wastes. This was attributed to the higher alum dosages that were used at the water treatment plants whose clarifiers were sampled, in comparison to the water plants with sedimentation.

Comments of Everhard and Freeman [3] suggest that alum levels found in the wastes of some plants are poisoning fish in the vicinity of the wastewater outfall. Only on-site studies could establish the existence of environmental problems.

2.3.5 Chemical analyses - Part 3

2.3.5.1 Trace metals. Samples of wastewaters were collected from 18 water plants throughout the province for trace metal analyses. The trace metals measured were as follows:

Chromium (Cr)
Zinc (Zn)
Copper (Cu)
Mercury (Hg)
Cadmium (Cd)
Nickel (Ni)
Manganese (Mn)

Over the past two or three years, concern about the effects of metals applied to soil has increased. If the disposal of water plant wastes is to be on agricultural land, the levels of certain metals should be known. For example, copper, nickel and zinc, if present in sufficiently high quantities, can be toxic to plants [11].

Research involving trace metals in the past has been hampered by the lack of sensitive analytical techniques. The complexity of toxicity tests on trace elements is great. A wide-ranging discussion on toxicity of trace elements has been presented by the Ontario Ministry of the Environment Laboratories Branch [12].

2.3.5.2 Results. The trace metal analytical data from several wastewater samples, taken throughout the province, are listed in Table 11.

TABLE 11. TRACE METAL ANALYSES

Plant	Waste Type	Total Solids* g/l	Metals µg/g dry weight						
			Cr	Zn	Cu	Hg**	Cd	Ni	Mn
Hamilton	Sed.	77.5	117	196	60	-	3	40	690
South Peel	Sed.	91.1	15	209	75	29	< 2	32	440
South Peel	Sed.	91.0	132	66	71	2	7.7	23	350
South Peel	Sed.	123	11	154	55	-	< 2	24	325
Toronto									
- Harris	Sed.	158	95	260	-	63	2.5	63	760
- Westerly	Sed.	171	24	46	14	-	-	19	94
Bowmanville	BW	0.33	121	151	182	-	<60	242	121
Windsor	Sed.	34	47	100	14	-	4	41	412
Amherstburg	C	4.4	60	230	69	-	23	207	598
Amherstburg	C	7.8	62	58	19	90	< 3	14	102
Union WSS	C	3.4	-	224	71	-	41	124	706
Union WSS	C	1.0	98	78	39	98	<20	<20	166
Niagara Falls	Sed.	60	83	98	37	158	6	28	350
Goderich	Sed.	140	-	-	-	20	-	-	-
Haileybury	Sed.	6.2	-	-	-	16	-	-	-
Ottawa									
- Lemieux	Sed.	9.3	38	16	<27	86	<11	<11	70
- Lemieux	Sed.	11.8	38	21	21	38	< 9	<30	68
- Britannia	Sed.	10.7	32	40	29	20	11	69	80
Thornbury	C	1.9	-	142	26	-	42	105	1,421
Lindsay	C	3.4	<12	59	<15	-	-	94	529
Sudbury	C	2.1	-	-	-	48	48	-	-
Cochrane	C	8.0	-	-	-	<13	-	-	-
Dresden	C	10.6	< 4	22	7.5	-	7	23	48,300
Brantford	Sed.	0.9	<45	<56	<11	-	<22	89	<45
Brantford	BW	0.78	<51	141	115	-	<26	77	154

* When sampled

** Nanogram dry weight

Repeated sampling of several plants, for example the South Peel WTP, produced widely divergent results on metals such as chromium and zinc but relatively constant levels on nickel and copper.

Generally speaking, the results for most metal plant wastes on Lakes Ontario and Erie were similar but were higher than for the Ottawa River plants. The manganese concentration at 48,300 µg/g dry wt was particularly high at Dresden. Potassium permanganate is used at that plant for the control of taste and odour.

2.3.6 Bacteriological analyses

Results of the bacteriological analyses carried out on samples taken from 25 water plants throughout the province are given in Table 12. There was little correlation between the raw water total plate counts and those from the backwash and sludge samples.

Prechlorination was practiced at most of the plants sampled. The sludge samples yielded the highest total plate counts found. Apparently, the surface-acting nature of chlorine prevented it from keeping the sludge low in bacteriological counts. Possibly, high bacteria levels (> 10,000 per ml) could disrupt the quality of the receiving stream, particularly when combined with the high BOD_5 characteristics of the waste.

2.4 Waste Characteristics Compared to Sewage Effluent

The characteristics of wastewater treatment plant effluents compared to water plant wastes have been summarized in Table 13. The sewage plants are all operated by the Ministry of the Environment and the average waste levels are computed from the 1973 Operating Summary [13].

A quick review of the levels of various waste parameters indicates that the "average" water works backwash was higher in suspended solids but lower in other parameters such as BOD_5, total phosphate, Kjeldahl nitrogen and nitrates than were sewage plants. Clarifier blowdown waste was much higher in suspended solids, lower in nitrates and nitrites but similar in all other parameters. The sedimentation basin sludge, even diluted 2:1, was much higher in all waste chemical characteristics indicated, except nitrates and nitrites.

The "average" sewage plant, however, discharges 20 - 30 times the waste volume of the "average" water plant.

TABLE 12. WASTEWATER BACTERIOLOGICAL ANALYSES

Plant	Total Plate Count per ml Raw Water	 Backwash Water	Sed. Basin or Clarifier Sludge
Blenheim	2,510	> 300,000	-
Port Dover	105	117	-
Rockland	10	-	30
St. Jacobs	2	16	-
Brockville	20	-	200
Campbellford	85	15	-
Cobourg	225	-	300
Deep River	7	0	-
Dresden	8,600	-	600
Grimsby	148	5,200	-
Markham	2	136	-
Perth	30	2,000	10,000
Richmond Hill	-	30	-
Elgin Area WSS	> 3,000	7,500	> 300,000
Belleville	-	-	59,000
Cornwall	7	-	> 300,000
Kingston	-	-	300,000
Hamilton	2	360	-
Lake Huron WSS	396	-	300,000
South Peel WSS	415	475	-
St. Catherines	25	2,200	300,000
Toronto			
- Island	5	110	-
- R.C. Harris	-	210	-
- Westerly	-	825	180,000

TABLE 13. QUALITY OF WASTEWATER DISCHARGE - MINISTRY WASTEWATER PLANT EFFLUENTS VS WATER PLANT WASTES

Type	Number	Chemical Analyses mg/l				
		Susp. Solids	BOD_5	P	Kjeldahl N	NO_3 + NO_2
Sewage Plants*						
Primary	14	73	84	4.3	20	0.6
Extended Aeration	13	20	13	3.6	7.7	6.2
Contact Stabilization	4	37	19	4.1	12.6	5.1
High Rate Act. Sludge	6	30	31	5.6	13.8	3.4
Conventional Act. Sludge	38	25	19	3.2	11.5	5.2
Single Cell Lagoon	17	46	21	3.2	13.5	-
Multi Cell Lagoon	30	33	20	2.8	7.9	-
Water Plants						
Backwash Water	29	230	7.3	0.6	3.5	< 0.2
Clarifier Blowdown	9	5,400	27	4.2	13.5	< 0.2
Sedimentation** Basin Discharge	18	23,000	375	22	90	< 0.2

* analyses not weighted in proportion

** diluted 2:1

3. WASTEWATER QUANTITY

3.1 General

Three methods were used to obtain the best possible data for determining the quantity of the wastes leaving the water plants. These were:

(1) examination of the daily operating records of the largest plants,

(2) mass balances on the solids entering and leaving several plants, and

(3) using the data from the questionnaire for those plants remotely situated from Toronto.

The results indicate that in 1973, an average of 85,400 lb (38,765 kg) of waste solid material and 19.3 million imperial gallons (87,735 m^3) were discharged to Ontario waterways each day. Lake Ontario received the largest amount of waste, with 44 percent of the solid waste and 58 percent of the liquid waste entering its waters. The four MOE regions in southern Ontario accounted equally for the bulk of all of the solid wastes produced. The MOE operated plants produced 17 percent of the solid and liquid wastes discharged by water treatment plants in the province.

The disposal method used by 95 out of the 105 water treatment plants studied was to discharge the wastewaters back into the waterway. The sludge volume discharged from any given plant equipped with sedimentation facilities was dependent on the raw water quality, the size of the plant, the chemicals used and the frequency of the cleaning operation. Total backwash volumes per unit filter area were consistent, regardless of the size of the plant, but the frequency of the wash cycle varied substantially.

3.2 Daily Operating Records used for Provincial Waste Quantities

The main aim of the sampling and visiting program was to visit those plants that were "typical" installations, in size and operation, of the large plants over 20 MIGPD (90,905 m^3/day).

To obtain an accurate estimate of the daily waste production over the entire year, the daily operating sheets were examined in 12 plants in Ontario. Details such as raw water flows, raw water turbidity, coagulant dosages and amount of filter backwash water were collected. Multiple samples were also obtained under a broad range of raw water conditions, to supplement the correlation between suspended solids and turbidity (Section 2.3.2.3).

For several plants, frequency curves were established to determine the solid and the liquid wastes leaving the water works. The reasons for these curves, the details for construction of the curves and the results are discussed in Appendix IV.

The waste quantities from all 12 plants, whose daily operating records were examined, are totalled in Table 14.

The extra time and effort expended on these 12 plants was thought to be justified since over 50 percent of both the solid and the liquid wastes of the provincial total was found to be discharged from these plants in 1973.

TABLE 14. DAILY OPERATING RECORDS - WASTE QUANTITIES

Number of Plants	Average Daily Volume MIGPD	Wastewater	
		Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
12	483.5 (66.0)	43,800 (51.3)	11.2 (58.0)

( ) percent of provincial total

3.3 Mass Balance Results Used for the Provincial Total

Mass balances were carried out at 26 water plants throughout Ontario. This approach was believed to give the best data for determining the location of the waste removal points within the plant as well as giving the quantity of the waste accumulated daily.

The plants were chosen because of the completeness of their operating records, type of treatment and raw water quality.

The locations of the suspended solids entering and leaving the plant are illustrated in Figure 12.

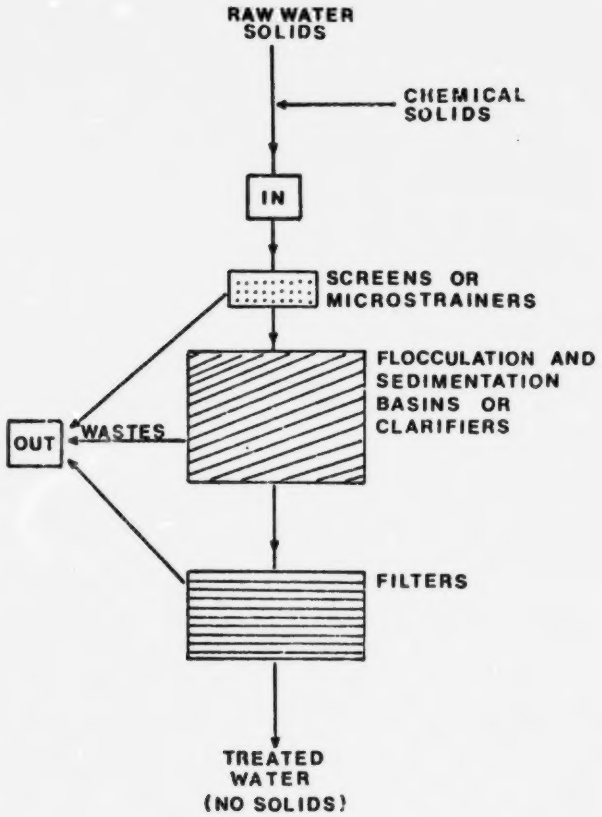
RAW WATER SOLIDS
CHEMICAL SOLIDS
IN
SCREENS OR MICROSTRAINERS
FLOCCULATION AND SEDIMENTATION BASINS OR CLARIFIERS
OUT
WASTES
FILTERS
TREATED WATER (NO SOLIDS)

FIGURE 12. LOCATION OF WASTE MATERIAL ENTERING AND LEAVING THE WATER TREATMENT SYSTEM

Appendix V outlines the methods by which the solids entering and leaving the water works were determined. Included in this Appendix are the locations from which the wastes, liquid and solid, were discharged. The mass balance results for the four main types of treatment methods are also given.

Of the 26 water plants that had mass balances carried out on their wastes, 16 were used to compute the average daily waste production for the provincial totals. The other 10 plants were examined more closely, using the daily operating sheets. The daily waste weights and volumes for the 16 plants are listed in Table 15.

TABLE 15. MASS BALANCE - WASTE QUANTITIES

Number of Plants	Average Daily Volume MIGPD	Wastewater	
		Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
16	60.5 (8.3)	14,800 (17.3)	2.4 (12.4)

( ) percent of provincial total

3.4 Questionnaire Yearly Average

The waste quantity calculations were made for 77 water treatment plants, based on the questionnaire data. These plants were in the smaller centres lying in the outer regions of the province.

The breakdown of the number and size of the 77 water plants, whose wastes were calculated in this manner, is given in Appendix VI. This Appendix also outlines the method of calculating waste quantities and gives a comparison of questionnaire vs daily records and questionnaire vs mass balance results.

The waste quantities from the 77 water plants that had their waste determined, using the questionnaire results, are listed in Table 16.

Although the number of plants involved was by far the majority of the water plants in Ontario, the solid and the liquid waste levels were only 30 percent of the provincial quantities.

TABLE 16. QUESTIONNAIRE RESULTS - WASTE QUANTITIES

Number of Plants	Average Daily Volume MIGPD	Wastewater	
		Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
77	189.0 (25.7)	26,800 (31.4)	5.7 (29.6)

( ) percent of provincial total

3.5 Summary of Waste Quantities

The total quantity of wastes produced in water treatment plants throughout the Province of Ontario is given in Table 17.

In 1973, the 105 plants produced 733 MIGPD (3,331,765 m^3/day) of treated water and discharged 85,400 lb (38,765 kg) of solid waste in 19.3 MIG (87,727 m^3) of liquid waste each day.

TABLE 17. PROVINCIAL WASTE QUANTITIES

Method of Determination	No. of Plants	Average Daily Volume MIGPD	Wastewater	
			Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
Daily Records	12	483.5 (66.0)	43,800 (51.3)	11.2 (58.0)
Mass Balance	16	60.5 (8.3)	14,800 (17.3)	2.4 (12.4)
Questionnaire	77	189.0 (25.7)	26,800 (31.4)	5.7 (29.6)
Totals	105	733 (100)	85,400 (100)	19.3 (100)

( ) percent of provincial total

3.5.1 Waterway waste breakdown

The waterway waste breakdown is summarized in Table 18.

TABLE 18. WATERWAY WASTE BREAKDOWN

Waterway	No. of Plants	Average Daily Volume MIGPD	Wastewater	
			Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
Lake Ontario	26	508	37,800	11.1
Lake Erie	16	64	14,550	2.3
Lake Huron	9	41	5,450	2.2
Northern Ontario Inland Waterways	14	13	3,200	0.5
Southern Ontario Inland Waterways	31	46	10,450	1.5
Ottawa River	9	61	13,950	1.7
Total	105	733	85,400	19.3

Lake Ontario and the St. Lawrence River, from St. Catherines to the Quebec border, had 26 plants discharging 37,800 lb (17,158 kg) per day in 11.1 MIG (50,455 m^3) of wastewater. Lake Erie, running from just below Sarnia to Niagara Falls had 16 plants discharging 14,500 lb (6,605 kg) per day in 2.3 MIG (10,455 m^3) of wastewater.

3.5.2 Regional Ministry and non-Ministry waste breakdown

The Ontario Ministry of the Environment regional operation divides the Province into six regions; this breakdown is shown in Figure 13.

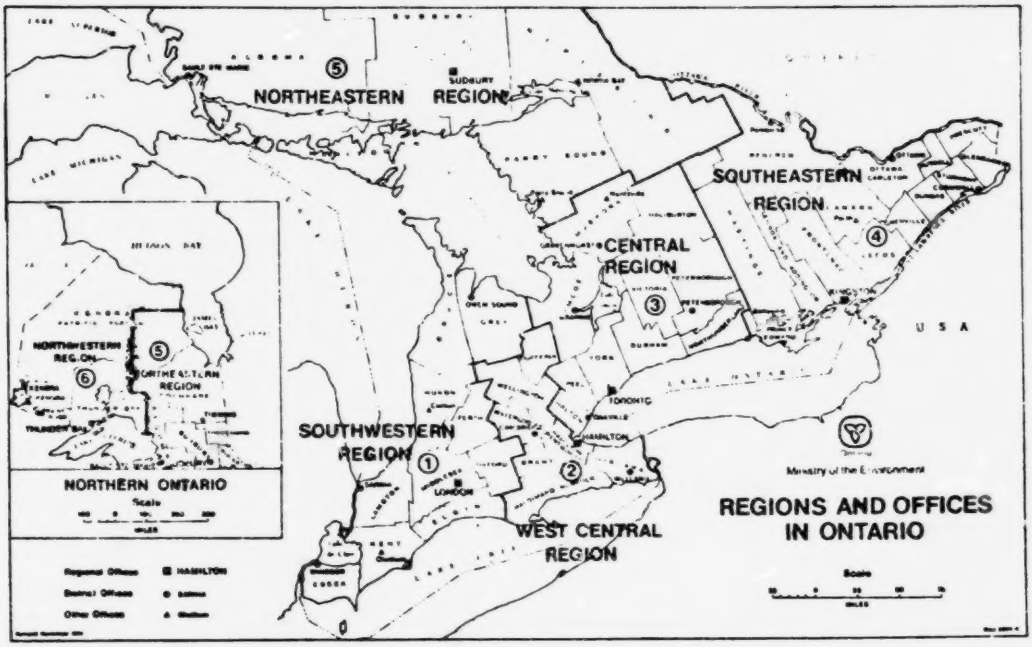
⑤
NORTHEASTERN REGION
SUDBURY
SOUTHEASTERN REGION
④
CENTRAL REGION
③
TORONTO
KINGSTON
U S A
NORTHWESTERN REGION
⑥
⑤
NORTHEASTERN REGION
NORTHERN ONTARIO
Scale
SOUTHWESTERN REGION
①
LONDON
②
HAMILTON
WEST CENTRAL REGION
Ministry of the Environment
REGIONS AND OFFICES IN ONTARIO
Scale
Regional Offices
District Offices
Other Offices
HAMILTON

FIGURE 13. ONTARIO MINISTRY OF THE ENVIRONMENT REGIONS

Table 19 shows that the two MOE Southern and the West Central Ontario Regions had approximately the same daily solid waste production, with the Central Region having the bulk of the liquid wastes.

TABLE 19. WATER PLANT REGIONAL BREAKDOWN

Region	No. of Plants	Average Daily Volume 1973 MIGPD	Wastewater	
			Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
Central	17	385	23,900	8.4
West Central	16	127	18,000	3.1
Southeastern	31	115	19,900	3.4
Southwestern	28	92	20,300	3.9
Northwestern	5	2	100	0.1
Northeastern	8	12	3,200	0.4
Totals	105	733	85,400	19.3

Table 20 shows that the Southwestern Region Ministry plants produced the most waste of the Ministry operated water plants. The seven plants in this region produced 43 percent of the solid waste and 59 percent of the liquid waste of all the MOE plants. Overall, the wastewater leaving the Ministry operated water plants accounted for 21 percent of the total weight of the solids and of the total volume of liquid waste discharged from all the water plants in Ontario in 1973.

TABLE 20. MINISTRY OPERATED WATER PLANTS REGIONAL BREAKDOWN

Region	No. of Plants	Average Daily Volume 1973 MIGPD	Wastewater	
			Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
Central	2	36.0	4,850	0.7
West Central	2	1.3	242	0.1
Southeastern	4	0.9	100	0.0
Southwestern	7	47.5	8,820	2.3
Northwestern	1	0.1	20	0.0
Northeastern	3	3.6	815	0.2
Totals	19	89.4	14,847	3.3

A comparison between Tables 20 and 21 indicates that a larger amount of wastewater was discharged from municipally operated water plants than from Ministry operated plants.

TABLE 21. NON-MINISTRY OPERATED WATER PLANTS MOE REGIONAL BREAKDOWN

Region	No. of Plants	Average Daily Volume 1973 MIGPD	Wastewater	
			Total Weight of Solids lb/day	Total Volume of Liquid MIGPD
Central	15	349.0	19,050	7.7
West Central	14	125.7	17,758	3.0
Southeastern	27	114.1	19,800	3.4
Southwestern	21	44.5	11,480	1.6
Northwestern	4	1.9	80	0.1
Northeastern	5	8.4	2,385	0.2
Totals	86	643.6	70,553	16.0

3.5.3 Water plant size vs waste breakdown

The relationship between the total daily flow of water plants and the solid and liquid wastes produced can be seen in Table 22.

TABLE 22. WATER PLANT SIZE VS WASTE QUANTITY

Size Range MIGPD	No. of Plants	Average Daily Volume MIGPD	Wastewater Total Weight of Solids lb/day	Wastewater Total Volume of Liquid MIGPD
> 20	10	537.0	49,500	12.8
5-20	14	111.8	19,100	3.6
0.5-5	45	74.2	13,400	2.4
< 0.5	36	10.0	3,400	0.5
Totals	105	733.0	85,400	19.3

The plants with an average daily production in excess of 20 MIGPD (90,905 m^3/day) had a total daily flow of 537.0 MIGPD (2,440,910 m^3/day) which is 73 percent of the provincial total. The 49,500 lb/day (22,470 kg/day) of solid waste and 12.8 MIGPD (58,180 m^3/day) of liquid waste was 58.0 percent and 66.3 percent, respectively, of the total provincial solids and liquid wastes produced daily. The lower percentage of solid waste is partially attributable to the superior raw water quality of the larger treatment plants. The 81 water plants producing less than 5.0 MIGPD (22,748 m^3/day) accounted for only 19.7 percent of the solid waste and 15 percent of the liquid waste produced daily in 1973.

3.6 Present Waste Disposal Practices in Ontario

Of the 105 water plants in Ontario that produced waste effluent, 95 discharged their wastes directly back into the waterway. The disposal practices of the other 10 plants are shown in Table 23.

Four plants discharged their wastewaters directly to the sewage plant with no flow restrictions. Six of the plants had lagoons, although only four of them had been in operation over three years. All of the 10 plants with a water production over 20 MIGPD (90,905 m^3/day) discharged their wastewaters back into the waterways.

TABLE 23. PRESENT WASTE DISPOSAL PRACTICES IN ONTARIO

Size Range MIGPD	Methods of Disposal		
	Waterway	Sewerage	Lagoons
> 20	10	0	0
5-20	12	1	1
0.5-5	37	2	5
< 0.5	36	1	0
Provincial Totals	95	4	6

3.6.1 Sedimentation basin disposal methods

The disposal practices of 47 out of the 54 water plants equipped with sedimentation basins are outlined in Table 24. Four of these plants were equipped with mechanical desludging equipment while the other 43 cleaned the basins manually using high pressure hoses. Basins cleaned by physical means were cleaned an average of 5.4 times per year.

TABLE 24. SEDIMENTATION BASIN SLUDGE DISPOSAL METHODS

Size Range MIGPD	No. of Plants*	Disposal		
		Mechanical	Physical	(times/year)
> 20	8	-	8	4
5-20	10	1	9	5
0.5-5	19	2	17	6
< 0.5	10	1	9	6
Total	47	4	43	5.4**

* No information was given to the questionnaire from the remaining seven plants.

** weighted volume average

3.6.2 Sludge volumes accumulated in sedimentation basins

Table 25 outlines the average sludge volume and cleaning frequency of both turbidity and colour removal plants that were equipped with sedimentation basins.

Both the sludge volume and cleaning frequency of the colour removal plants were far greater than those of the turbidity removal plants. This was attributed directly to the larger alum dosages required to remove colour from the water.

TABLE 25. SEDIMENTATION BASIN SLUDGE VOLUMES

Turbidity Removal Plants

Size Range MIGPD	No. of Plants*	Average Sludge Volume ft^3/yr	Average Sludge Volume per Sedimentation Basin Area $ft^3/yr/ft^2$	Cleaning Frequency times/yr
> 20	6	112,300	1.7	2.2
5-20	6	83,800	4.0	2.5
0.5-5	10	25,400	5.6	4.4
< 0.5	5	3,370	3.5	7.0

Colour Removal Plants

Size Range MIGPD	No. of Plants**	Average Sludge Volume ft^3/yr	Average Sludge Volume per Sedimentation Basin Area $ft^3/yr/ft^2$	Cleaning Frequency times/yr
> 20	2	475,000	13.8	9
5-20	2	220,000	16.7	16
0.5-5	6	20,000	9.9	7
< 0.5	2	15,600	16.5	8

* 27 of the 37 turbidity removal plants are equipped with sedimentation basins (95% of turbid water flow)

** 12 of the 17 colour removal plants are equipped with sedimentation basins (93% of coloured water flow)

3.6.3 Clarifier blowdown practices

The practices of 19 of the 21 water plants equipped with solids contact clarifiers are given in Table 26. Only three plants were operated manually with blowdown usually taking place in the morning. During periods of high turbidity, the frequency of blowdown was increased proportionately. Of the 16 plants equipped with automatic blowdown systems only one, a partial softening plant, had a continuous discharge.

TABLE 26. CLARIFIER BLOWDOWN PRACTICES

Size Range MIGPD	No. of Plants*			
	Manual	Frequency Range times/day	Automatic	Frequency Range times/day
5-20	0	-	2	33-144
0.5-5	1	1	7	1-continuous
< 0.5	2	1-4	7	1-60

* No information on blowdown practices was given for two plants.

3.6.4 Filter backwash water volumes and techniques

Data were assembled from the questionnaires on the filter wash practices of 92 water plants in Ontario. The findings are listed in Table 27. Most plants with an average daily production in excess of 20 MIGPD (90,905 m^3/day) backwash the filters at a predetermined headloss rather than on a time basis. The smaller plants of less than 0.5 MIGPD (2,281 m^3/day) usually backwash the filters at a predetermined time. The average amount of water usually produced per unit filter area prior to the backwash and the average quantity of water used to clean the filter per unit filter area was similar for all plant size ranges.

The large plants (>20 MIGPD) had a backwash volume percentage of 2.3. This percentage was heavily weighted by the extremely large water plants producing over 50 MIGPD (227,270 m^3/day). The percentage of treated water used to backwash the filters was found to be less for the larger water plants. This was attributed to the larger plants treating a better quality of raw water as well as the fact that manpower and control equipment were available.

The average length of filter run was in the 30 to 60 hour range; however, short filter runs were experienced in many plants during periods of high algae or high raw water turbidity conditions.

TABLE 27. FILTER BACKWASH VOLUMES AND TECHNIQUES IN ONTARIO

Size Range MIGPD	No.*	Backwash on Time	Backwash at set Headloss	Ave*** Water Filtered IG/ft^2	Ave*** Backwash Water IG/ft^2	Ave*** % of Treated Water	Ave*** Filter Run (hrs)
> 20	10	2	8	2,800	110	2.3	40
5-20	14	5	9	3,160	109	3.0	46
0.5-5	37	16	21	3,260	110	4.5	38
< 0.5	31	18	13	3,120	118	5.8	44
Total	92	41	51	2,906**	110**	2.6**	41**

* No information was given in the questionnaire for the remaining 13 plants

** Weighted volume averages

*** Arithmetic Averages

4. WASTEWATER TREATMENT AND DISPOSAL

4.1 General

The literature search portion of this study was intended to provide background on previous work and on that which is taking place on the collection, treatment and disposal of wastewaters from water treatment plants.

There are several approaches being taken at water plants to restrict wastewater discharge. These include dewatering followed by physical removal from the plant, direct discharge to sanitary sewers, or recycling the waste back into the raw water inflow.

Extensive research has been undertaken in all of these areas. The highlights of this research and pertinent findings of the questionnaire survey are outlined in this Section.

4.2 Background

Many reports have been issued in the last few years on wastewater disposal from water treatment plants. In 1968, Oda of the Ontario Water Resources Commission [14] carried out a comprehensive literature search on the state of the art of water works waste treatment and disposal. Doe [15] issued a report on the practices and facilities of sludge disposal from water treatment plants. The information was a result of a four month study tour in the United States, the United Kingdon and several other European countries. The American Water Works Association has been closely following the progress of wastewater disposal practices across North America and has issued several status reports [16]. In 1971, the Water Research Association (WRA) in England undertook a review of sludge treatment and disposal practice [17]. In 1974, the WRA issued a report [18] summarizing the information and methods of evaluating WTP sludge works as presented during the 1972 Regional Meetings. Dick [19] summarized the attitudes in sludge treatment and disposal and suggested that there was a need to not only improve the technology of sludge treatment, handling and disposal schemes but also to re-evaluate some of the basic approaches to the problem.

4.3 Treatment and Disposal Methods

As outlined earlier in Section 3.6 almost all of Ontario's water treatment plants that produce waste dispose of it into the nearest receiving stream. If restrictions of this wastewater practice are to be contemplated, the alternatives become the important issue in dealing with the problem. At present, these alternatives include:

(1) dewatering followed by ultimate disposal,
(2) sewerage,
(3) recycling and/or coagulant recovery.

A general outline of each of these methods is given in this section. The pertinent results of pilot plant or full scale research of each of the methods in these fields are also included. The applicability to Ontario's conditions and cost estimates for the most appropriate methods are given in Section 5.

4.4 Dewatering

The treatment of water works waste sludges and backwash waters may include a dewatering step. In the case of sludge incineration, this is a necessary step to reduce the cost of incineration. Other possible reasons for dewatering include reducing transportation costs or converting the sludge into a form that is suitable for landfill.

Dewatering may be accomplished by natural or mechanical means. Figure 14 outlines the subsections to each of these methods. Natural dewatering includes the use of lagoons. Under the proper climatic conditions, a freeze-thaw or drying technique may be adopted. Mechanical dewatering may be carried out with filter presses, vacuum filtration, or centrifugation.

4.4.1 Natural dewatering

4.4.1.1 Lagoons. Sludge disposal by lagooning is an economical solution in areas where ample land is available and where it is not unsightly. Lagoons can be used only for a limited time as ultimately they will have to be cleaned out or covered over. Alum sludge gradually consolidates up to 8 to 15 percent solids in lagoons but there are exceptions. The removal

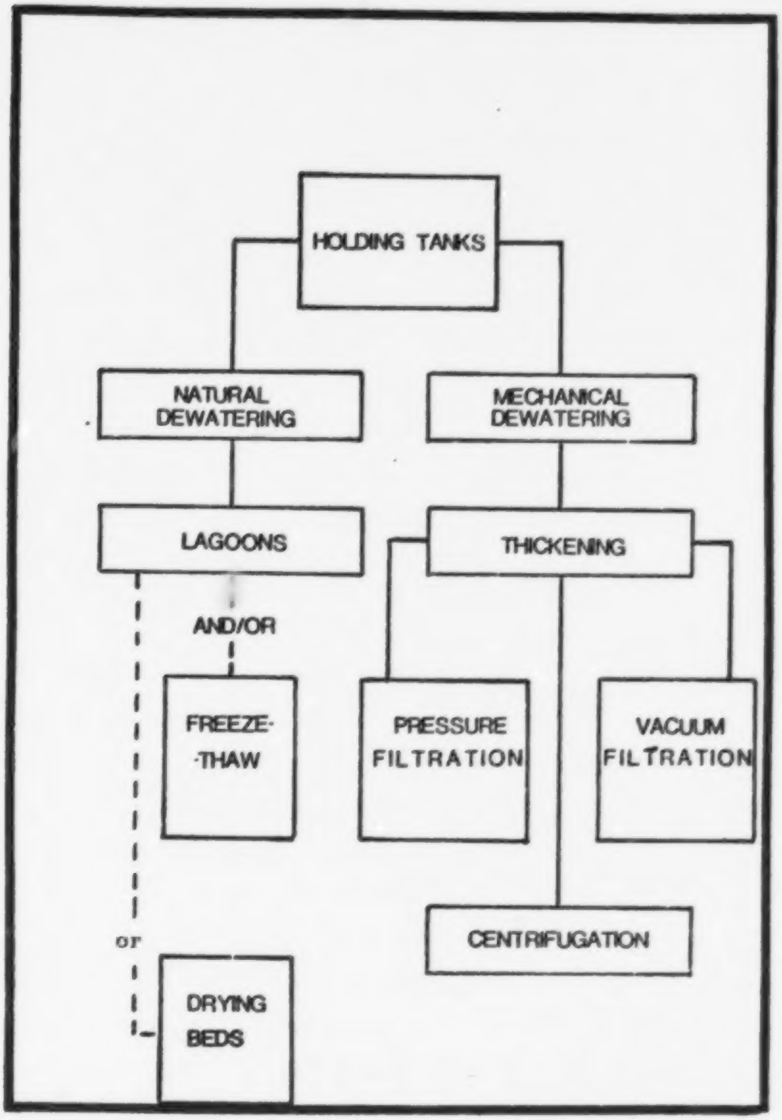
HOLDING TANKS
NATURAL DEWATERING
MECHANICAL DEWATERING
LAGOONS
THICKENING
AND/OR
FREEZE-THAW
PRESSURE FILTRATION
VACUUM FILTRATION
CENTRIFUGATION
or
DRYING BEDS

FIGURE 14. NATURAL AND MECHANICAL METHODS OF DEWATERING WASTEWATERS

of the liquid from the lagoon takes place by natural drainage, seepage through an underdrain system or evaporation. The removal of the sludge from the drained lagoon can take a variety of forms, such as dredging or by dragline.

The design and operation of dewatering has been outlined [18]. Most rules for the design of lagoons are common sense guidelines. A preference is given for a minimum of six or seven small lagoons over a smaller number of large lagoons. Additional technical aspects for several water plants are documented by Doe [15] and the AWWA Research Foundation [20].

The applicability of lagoons to the Ontario situation is partially outlined by the questionnaire response. The survey responses to the question "Is suitable land available near your plant for lagoon(s)?" are given in Table 28.

TABLE 28. QUESTIONNAIRE RESPONSE TO "IS SUITABLE LAND AVAILABLE NEAR YOU PLANT FOR LAGOON(S)?"

	YES			NO		
Size Range MIGPD	No. of Plants	Volume MIGPD	% of Size Range Total	No. of Plants	Volume MIGPD	% of Size Range Total
20	5	188	35	5	346	65
5-20	7	44	42	7	61	58
0.5-5	20	35	53	18	30.8	47
< 0.5	14	4.5	54	13	3.8	46

The results indicate that, of the 89 plants processing 97 percent of the treated water in Ontario that answered this question, 46 plants had suitable land available.

The percentage of positive replies is felt to be a maximum value as no definition of the term "suitable" was requested. Without details of the size of any lagoon and soil characteristics, the term "suitable" could be liberally interpreted and a positive answer may be incorrect. However, on the other hand, most negative answers are felt to be accurate.

Of the six water plants in Ontario that currently lagoon their waste two, at Deep River and Bowmanville, have been in operation for less than three years. The iron removal plants at Georgetown and Richmond Hill lagoon their backwash water with seepage through the soil accounting for the removal of the liquid. The 'natural' lagoon at Brantford was badly damaged by the 1974 flood and its status is currently under review. The 'natural' lagoon at Tilbury is dredged every ten years and the sludge spread on the nearby marshy land.

4.4.1.2 Freeze-thaw. This method of dewatering alum sludge was studied by Doe in 1958 [15] and again by Ferrel in 1970 [21]. A physical change occurs in the solids during the freezing cycle of water works sludges. The colloidal sludge is broken down. On thawing, the sludge becomes a clear supernatant with small granular sludge particles occupying about one-sixth of the original sludge volume [22].

The advantage of freezing is that it produces a material that can be conveniently handled (solids concentration of 20 percent plus) for subsequent disposal, drains almost immediately and is suitable for landfill. To be economical, freezing has to be carried out naturally in a cold climate using thin layers of sludge.

In the Ontario climate where frost occurs frequently during the winter period, natural freezing of alum sludge is a distinct possibility. The Copenhagen WTP [16] has been using this method for alum sludge dewatering since 1963. The freezing of the sludge occurs in lagoons which have a drained gravel bottom, to an effective depth of one metre. As a result, the amount of sludge remaining after two years of operation consisted of a layer about 4 cm deep.

Some recent work by Todd and Koseric on the Elgin Area Water System shows that freezing and thawing may be an economically feasible method of dewatering alum sludge in Ontario [23]. Their results indicated that upon freezing and thawing, the physical characteristics of the alum sludge changed drastically. The sludge settled rapidly and the raw sludge solids content increased from 8 to 30 percent following freezing.

It was also found that the freezing process was enhanced by spraying the sludge through fire hose nozzles which allowed the sludge to cool as it passed through the air. This not only permitted uniform distribution of the sludge in the lagoon but melted any snow cover which would otherwise have provided insulation hindering freezing.

4.4.1.3 Sludge drying beds. In contrast to lagoons, sludge drying beds are designed and built to provide for underdrainage of the sludge [18] and they are commonly used in dewatering sewage sludges [8]. Only limited use has been made of sand drying beds for water works sludge.

The WRA has undertaken tests on sand drying beds at Manchester Corporation water works, the details of which are outlined in a technical report [17]. They found that poor drying took place in the winter months and an excessive area of drying beds was needed. The effectiveness was governed by the climatic conditions of the locality.

The efficiency of the drying process is dependent on the evaporation and/or natural drainage of the bed. Specific design parameters such as the underdrainage system, permeability, porosity, media uniformity coefficient, bed loading, distribution method and supernatant collection are but a few that should be carefully determined for each utility [24].

Sludge drying beds in sewage treatment installations involve a high labour cost for the removal of dried sludge; this made the process attractive in small- to medium-sized plants only. The WRA is testing a porous concrete as a drainage media to allow equipment such as front end loaders to remove the sludge from the beds [17]. The economics of other underdrain facilities, such as wedge-wire, should be evaluated on these grounds. The advantages over the conventional type of drying bed are outlined by Oda [14].

4.4.2 Mechanical dewatering

4.4.2.1 Settling, thickening, conditioning. Concentration of sedimentation basin, clarifier or filter wash waste may be necessary to treat or dispose economically of the waste. The popular methods available to concentrate the wastes are shown in Figure 15.

Settling. Settling is the process in which wastewater is directed into a settling basin or clarifier and the supernatant is drawn off from the top and the more concentrated sludge is withdrawn from the base. As discussed in Section 2.3.2.4, the characteristics of the sludge have a great influence on the settling behavior.

Thickening. Thickening is achieved by slowly stirring the sludge in a tank. The characteristics of the sludge have a significant influence on the efficiency of the thickening process. Gauntlett [25]

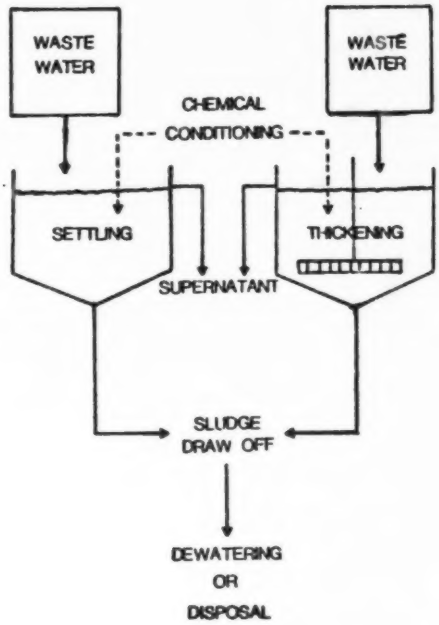

FIGURE 15. METHODS OF CONCENTRATING WASTES

worked on several water works sludges and concluded that the gelatinous metal hydroxide content and the particle size were two important factors in determining sludge thickening efficiencies. In full scale tests, the Fylde Water Board found that by slow stirring a water works waste of 0.03 to 0.04 percent solids for eight hours, a sludge of 2.5 to 3 percent solids was obtained [17]. Addition of polyelectrolytes or lime aided the above process. Kos and Adrian [26] investigated batch and continuous gravity thickening of various sludges and found that they were normally able to obtain thickened sludges of 3 to 5 percent solids.

Conditioning. Conditioning a sludge is the process of adding specific amounts of chemicals to change the characteristics of the suspended solids in the sludge so that they can be more easily separated from the liquid. The chemicals used were usually lime or polyelectrolytes. The use of lime and polymers in specific mechanical dewatering processes is also outlined.

4.4.2.2 Filter pressing. The filter pressing process operates by pumping sludge at high pressure against a filter cloth. The solid cake builds up on the cloth while the water passes through.

Until recently the filter press was not used extensively for treatment of water works sludges. Problems with highly variable sludge characteristics and because it is a batch process may have been the reasons for the limited use.

The introduction of polymers for conditioning sludges, new filter cloth materials and some automation in the process have contributed to filter pressing's recent popularity. Conditioning the coagulant sludges improved the filterability and reduced the pressing time in a number of cases [16, 17, 18 and 27]. Precoating the media prevented clogging and ensured a clean break of the cake from the filter media when the cake was discharged.

Pilot plant studies at several water plants in the United States have shown that the low concentration filter backwash sludges were more difficult to dewater than those from the sedimentation basins on the clarifiers.

Alum sludges may be dewatered to give final cake solids of 40 to 50 percent [27]. Naturally, this would result in lower land requirements for sludge disposal. Other advantages include a low suspended solids level in the filtrate as well as operating flexibility on a variety of water plant sludges.

The research panel established by the Institution of Water Engineers and the Society for Water Treatment and Examination on Disposal of Water Works Sludge recommended this method for dewatering of water works coagulation sludges [28].

4.4.2.3 Vacuum filtration. Figure 16 is a schematic depiction of a rotary vacuum filtration system. The (precoated) drum is partially submerged into the sludge and is continuously rotated with constant vacuum applied to the cake. The liquid is drawn through the septum and vacuum lines and into a receiver. The sludge solids are entrapped and build up on the surface of the belt and the cake.

The literature suggests that vacuum filters are more applicable to "softening" sludges than to most alum sludges. However, work carried out in Albany N.Y. [28] on a pilot plant indicated that vacuum filtration was economically and practically feasible. Sludge solids were increased to around 30 percent from inlet wastes of 0.3 percent. Westerhoff and Daly [27] obtained a final sludge solids content of 20 to 34 percent but costs made this technique prohibitive compared to other methods.

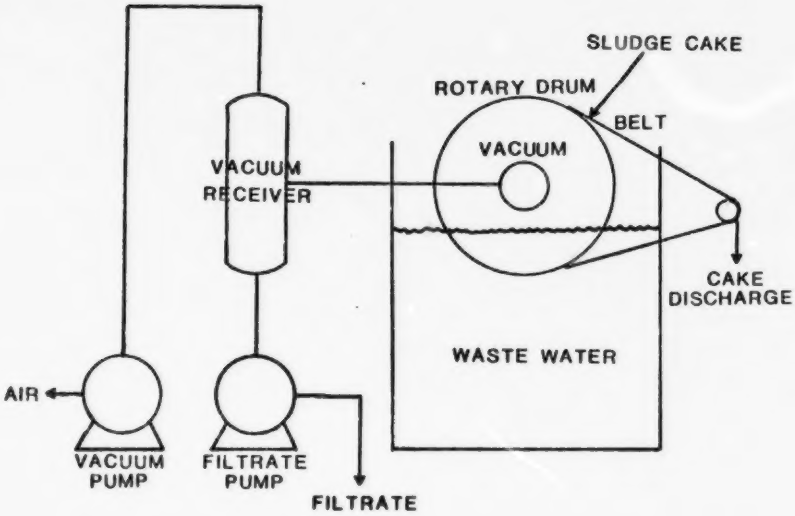

FIGURE 16. ROTARY VACUUM FILTRATION

4.4.2.4 Centrifugation. Centrifugation for dewatering sludges has been used extensively in the United States for lime softening sludges. The probable reason for the success of this method is the high ratio of solids weight to liquid weight.

Investigations conducted on dewatering alum sludges by this method have been without success [16, 17 and 18]. While a solids content of 20 to 30 percent is generally accepted as being the minimum for handling and disposal of alum sludges, the level of solids obtained by most researchers has been 6 to 19 percent. Westerhoff and Daly [26], working with a Scroll centrifuge at a Lake Erie water plant, obtained solids concentrations of 21 percent and 28 percent on the filter backwash and sedimentation basin sludges, respectively. A sludge concentration of 20 percent is truckable and is similar to soft wet clay. Filtrate suspended solids were around 550 mg/l.

4.5 Sludge Disposal

Whether the sludge has been dewatered by mechanical or natural means, the problem of the ultimate disposal site arises. The available methods include barging to sea, an unreasonable disposal method for Ontario, dumping in sanitary landfill sites, spreading on recreational or farm land, incineration, or hauling to a central location for storage and/or recycling.

Currently, most sanitary landfill sites in Ontario are independently operated. The probability of most of these sites accepting sludge which is not in a cake form is felt to be low. Sludge of a density such that vehicles can drive on it is more likely to be acceptable to site operators. The disposal of liquid waste sludges in sanitary landfills on specially selected sites is discussed in some detail by several authors including Simmons and Bowers [29].

The experience gained from the current spreading of pollution control plant sludge on farm land will be of importance to the water works engineer. Many sewage plants, particularly those located in the Lake Erie drainage basin, had converted to phosphorus removal treatment by December 31, 1973. Aluminum sulphate is one of several coagulants that are being used to precipitate the phosphorus. The effect on land application of sludges resulting from treatment with this chemical is currently under review.

Incineration of water treatment sludges has not been successful to date, because of the inert nature of the solid material in the sludge.

Haulage to a central regional location for possible treatment and/or recycling has recently been discussed with regard to sewage sludges. The possibility of some water plant sludges being treated in this manner is discussed more fully in Section 5.

4.6 Discharge to Sanitary Sewers

In four cases in Ontario, the water plants dispose of wastewaters directly into sewers. This is a convenient method when the quantity of sludge is small compared to that of the sewage flow and when the sewage processes are not disturbed by the type of water works waste. Two plants, at St. Jacobs and at Markham, are iron removal plants. They, as well as the plants in Cornwall and Campbellford, have no restrictions on the rate of wastewater flow. No complaints were received from the sewage plants and only a slight hydraulic surge was noted.

Most papers reviewing sewerage as a disposal method recommend that several restrictions be placed on the type and quantity of the waste discharge. These are reviewed in more detail in Section 5.

Information on the nearest sanitary sewer to the water plant was requested in the questionnaire. The results are indicated in Table 29. The response from the 88 plants that were able to answer the question indicated that 14 plants had no sewer nearby and 22 plants had sewers over 1,000 feet (305 metres) away. For 52 plants, sewerage of the wastes was feasible in terms of distance - < 1,000 feet (305 metres).

Doe [15] outlined the operation of two water plants in the United States that sewered their waste. He added the important point that, in each case, the water supply and sewage disposal were both administered by a single department, and that this had no doubt influenced the decision to adopt this particular method of disposal.

Possible advantages of disposing of the waste to the sewerage system include:

1. improved phosphate removal [30, 31 and 32],
2. COD reductions of up to 100 percent [30],
3. improved suspended solids removal [30].

O'Blenis and Warriner [30] found that the performance of the primary treatment plant was not impaired at dosage levels up to 10 percent of the hydraulic wastewater flow. However, this work was carried out prior to the commencement of the phosphate removal program in Ontario. The phosphate removal program uses alum or ferric chloride to reduce the phosphate levels in the sewage effluent. The effect of water works waste on sewage already being treated with a coagulant is unknown. However, there would probably be a reduction in the coagulant demand of the sewage.

4.7 Recycle/Coagulant Recovery

Waste volumes may be reduced by recycling part or all of the wastewaters back into the influent stream. This is one of the principles

TABLE 29. APPROXIMATE DISTANCE TO NEAREST SANITARY SEWER VS PLANT SIZE RANGE

Plant Size	0 - 100 ft.		100 - 500 ft.		500 - 1000 ft.		1000 ft. - 1 mile		Over 1 mile		None		Unknown	
MIGPD	No.	Volume MIGPD	No.	Volume MIGPD	No.	Volume MIGPD	No.	Volume MIGPD	No.	Volume MIGPD	No.	Volume MIGPD	No.	Volume MIGPD
> 20	3	165.0	2	216.0	-	-	2	72.0	2	61.0	1	23.0	0	0
5-20	6	50.0	4	39.8	2	12.0	-	-	1	3.0	1	7.0	0	0
0.5-5	14	23.7	6	11.8	3	4.8	6	12.7	3	6.9	6	8.1	7	6.2
< 0.5	5	1.8	3	1.1	4	1.1	5	1.8	3	0.6	6	1.4	10	2.2
TOTALS	28	240.5	15	268.7	9	17.9	13	86.5	9	71.5	14	39.5	17	8.4

of operation of solids contact clarifiers. The coagulated particles serve as a ready-made nucleus and promote floc growth and often lower the coagulant demand of the raw water.

Researchers have found that recycling the backwash water at a rate of 2 percent of the raw water flow would enhance the rate of removal of both colour and turbidity [33]. Oda stated in his literature search that the practice of re-using sedimentation basin sludge was very rare although several plants frequently recycled backwash water [14]. The re-use of sedimentation basin sludge would involve considerable handling which was generally uneconomical.

Magnesium carbonate, a recyclable coagulant, has been studied extensively at Dayton, Ohio, but has not been tested in Ontario to date [34].

Alum recovery has been successfully used for several years in Japan [35]. The process is outlined in Figure 17. The wastewaters are collected and thickened with the supernatant being recycled back into the treatment system. The sludge is acidulated with sulphuric acid to convert the aluminum hydroxide back into the soluble aluminum sulphate form. The inert solids are then disposed of by conventional means and the aluminum sulphate is used to supplement the alum supply.

On a pilot plant scale Westerhoff found that 75 percent of the alum could be recovered while full scale Japanese plants recover 50 to 70 percent [26]. Alum recovery facilities have been used at Tampa, Florida, primarily for cost savings, not for waste treatment [36].

4.8 Review of Waste Treatment Options

The following methods are the waste treatment options using existing technology.

4.8.1 Direct discharge to surface waters

Under the proposed regulations governing water treatment plant discharge, direct discharge to surface waters would be possible only for material removed from travelling screens treating water which had not been chlorinated. This waste would not have undergone any chemical treatment and would be suitable for discharge, in a controlled manner, back to the original water source.

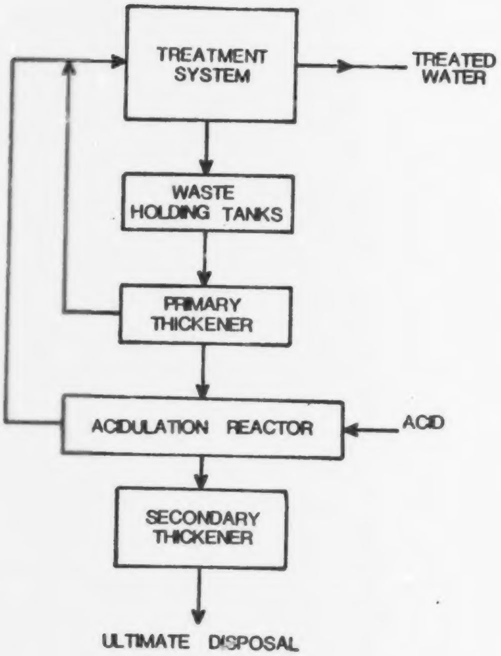
TREATMENT SYSTEM
TREATED WATER
WASTE HOLDING TANKS
PRIMARY THICKENER
ACIDULATION REACTOR
ACID
SECONDARY THICKENER
ULTIMATE DISPOSAL

FIGURE 17. ALUM RECOVERY FLOW DIAGRAM

4.8.2 Barging to sea

While discharge to the sea is a fairly common disposal method, it is out of the question for all Ontario water treatment plants.

4.8.3 Lagooning

Treatment of water plant wastes by retention in a lagoon is practical only at water treatment plants producing small quantities of waste and thus requiring only small areas for lagoons. Probably the sludge concentration after lagooning would rarely exceed 5 percent solids for alum sludge.

4.8.4 Sand bed drying

Sand bed drying depends mostly on evaporation of water from the bed and partly on filtration of entrained water through a gravel under-drain. The climatic conditions in Ontario are not suitable for this type of operation, without the use of covered beds and a controlled drying environment.

4.8.5 Discharge to sanitary sewers

From the standpoint of the water plant, discharge to a sanitary sewer is a simple method of waste treatment.

In small concentrations, alum sludges are reported to have little or no detrimental effect on the sewage treatment process [30].

Provided that the water treatment plant waste flow is discharged so as not to adversely affect the operation of the sewage treatment plant, there should be no problems.

The disposal of water plant waste to the sewage treatment plant imposes a hydraulic load on the system, and the suspended solids present in the water plant waste will impose a solids load at the sewage treatment plant, both of which will increase the total operating cost of the sewerage system.

4.8.6 Freezing

Ontario's temperature range is broad. The minimum "freezing-degree-days"* can range from 400 to much greater than 2,000. Under these conditions it is possible to freeze alum sludge in a shallow on-site lagoon. After thawing, the alum sludge will be at a concentration of approximately 30 percent solids and is in a suitable form for disposal and landfill. The major disadvantage of a sludge freezing system is that sludge must be stored for the entire summer and fall months before freezing can start, around December. This requires large areas of land.

4.8.7 Vacuum filtration

Filtration of alum sludges with vacuum filters has met with limited success. The filter cake produced is usually in the range of 20 to 30 percent solids and is not completely suitable for disposal to landfill. Sludge preconditioning may be necessary to ensure an adequate operation of the vacuum filter system.

4.8.8 Centrifuging

Centrifuging of alum sludge has met with only limited success due to the gelatinous nature of water plant sludge. For this reason centrifuging is not suitable, in general, for the handling of alum sludges.

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* Number of days x (32-T) (below $32^{\circ}F$).

4.8.9 Filter pressing

Pressure filtration of alum sludge, conditioned with lime and/or polymers, has been practised in a number of different locations and has met with considerable success. The filter cake is normally better than 35 percent solids, and is suitable for disposal to a landfill site. Operation of the filter press unit requires a greater input of labour than either centrifuging or vacuum filtration.

4.8.10 Coagulant recovery

Alum recovery has been established as a successful process in a number of pilot installations. The recovery process requires trained chemical operators. There is no recorded information on uptake of either flocculated colour or iron from the alum sludge after acidification and until these problems are thoroughly researched, recovery cannot be considered as a strong alternative for treatment of these wastes.

4.8.11 Summary

Table 30 summarizes the waste treatment options, and the waste treatment problems in Ontario. Shown in this table are the technically feasible combinations of waste treatment options and type of waste. Also shown are those options considered in detail in Section 5.

TABLE 30. POSSIBLE TREATMENT OPTIONS FOR VARIOUS WASTE TYPES

PRINCIPAL WATER TREATMENT PROBLEMS IN ONTARIO	TURBIDITY	COLOUR	ALGAE	OTHER
PERCENTAGE OF TOTAL BY FLOW 1973	84.1	13.2	1.6	1.1
PERCENTAGE OF TOTAL BY SOLIDS 1973	72.9	23.9	1.3	1.9
DIRECT DISCHARGE TO SURFACE WATERS	○	○	○	○
BARGING TO SEA	○	○	○	○
LAGOONING	●	●	○	○
SAND BED DRYING	○	○	x	○
DISCHARGE TO SANITARY SEWERS	●	●	○	○
FREEZING	●	●	○	○
VACUUM FILTRATION	○	○	○	○
CENTRIFUGING	○	○	○	○
FILTER PRESSING	●	●	○	○
COAGULANT RECOVERY	●	x	x	○

● TECHNICALLY FEASIBLE AND CONSIDERED EXTENSIVELY HEREIN

○ TECHNICALLY FEASIBLE PROVIDED APPROPRIATE CONDITIONS EXIST

X NOT FEASIBLE

5. COST ESTIMATES

5.1 General

A review of the treatment process information gathered during the MOE survey in mid-1974 showed that the majority of the plants surveyed listed either turbidity removal or colour removal as their major treatment problem. The WTP breakdown by process classification shown in Table 31 indicates their major significance from the standpoint of overall flow. For this reason they will be discussed in detail.

TABLE 31. WTP BREAKDOWN BY PROCESS CLASSIFICATION

Process	No. of Plants	Total Volume MIGPD*	% of Total Flow
Turbidity removal	63	617.6	84.2
Colour removal	30	96.7	13.2
Algae removal	4	11.8	1.6
Iron removal	8	6.9	1.0
Total	105	733.0	100.0

Both the turbidity and colour treatment processes involve the use of aluminum sulphate as coagulant; no other coagulant was shown, in the survey, as being used at present. This means that the waste treatment process required for the majority of Ontario water treatment plants is for alum sludge and alum bearing filter backwash water.

The treatment plant classification, therefore, has been broken down into two sub-sections only: plants which produce an alum sludge from removing turbidity alone ('Turbidity' plants), and those which produce an alum sludge by removing both turbidity and colour ('Colour' plants).

5.2 Water Purification Plant Models

5.2.1 Necessity for the use of a model

Within the limits of the study, individual discussion for each plant was not possible. The broad objectives of this section of the study were to indicate overall treatment costs rather than individual plant costs. Therefore, typical processes were selected to represent or "model" the turbidity and colour treatment processes.

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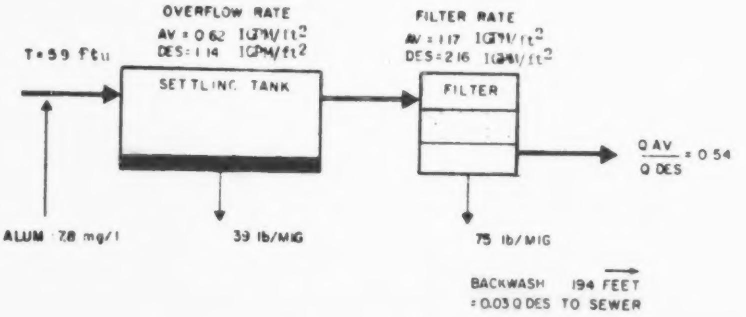
* Total MIGPD refers to summated 1973 average day capacities recorded in the survey (mid-1974).

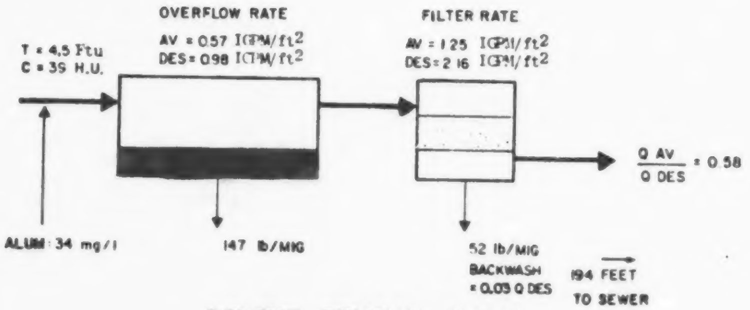
Complete details on the derivation of the models are included in Appendix VII.

5.2.2 Summary

Figure 18 summarizes all the information relating to the model plant derived in Appendix VII.


OVERFLOW RATE
AV = 0.62 IGPM/ft2
DES = 1.14 IGPM/ft2
T = 5.9 Ftu
SETTLING TANK
FILTER RATE
AV = 1.17 IGPM/ft2
DES = 2.16 IGPM/ft2
FILTER
Q AV / Q DES = 0.54
ALUM 7.8 mg/l
39 lb/MIG
75 lb/MIG
BACKWASH = 0.03 Q DES
194 FEET TO SEWER

TURBIDITY REMOVAL MODEL


OVERFLOW RATE
AV = 0.57 IGPM/ft2
DES = 0.98 IGPM/ft2
T = 4,5 Ftu
C = 39 H.U.
FILTER RATE
AV = 1.25 IGPM/ft2
DES = 2.16 IGPM/ft2
Q AV / Q DES = 0.58
ALUM: 34 mg/l
147 lb/MIG
52 lb/MIG
BACKWASH = 0.03 Q DES
194 FEET TO SEWER

COLOUR REMOVAL MODEL

T = turbidity   Des = design   C = colour   Q = raw water flow

FIGURE 18. SUMMARY OF TURBIDITY AND COLOUR REMOVAL MODEL PLANTS

5.3 Estimated Costs for Waste Treatment

5.3.1 General

The cost datum of December, 1973 was established for this study. This was selected because it coincided with the end of the period covered by the MOE questionnaire. The selection of any other point in time would require estimating the conditions which existed at all of the water plants in Ontario. We realize that 1973 cost estimates will not be particularly useful to all readers; therefore, an extension to mid-1975 will be provided for the overall costs later.

The total annual costs were based on operating conditions as they existed at the water plants in 1973. These costs will, therefore, be representative of actual 1973 costs in Ontario had waste treatment facilities existed during that year, at every existing water treatment plant. This is obviously a hypothetical state but does typify an actual set of operating conditions.

5.3.2 Capital cost estimates

All capital costs for the items of equipment comprising each process have been adjusted, using the Southam Construction Index, to December, 1973.

Prices for mechanical equipment were obtained from equipment suppliers; the prices for the other major process items were estimated using tender price surveys for completed water and sewage treatment plant projects, with prices adjusted using the Southam Construction Index.

5.3.3 Annual cost estimates

Debt retirement was considered an annual cost, and the debt was assumed to be amortised over a 25 year period at 10 percent interest. This results in an annual debt cost of $110.17 per $1,000.

The annual operating costs comprised chemical costs, maintenance, plant labour and sludge disposal.

Chemical costs were based on 1973 prices for the southern Ontario region.

Maintenance costs were based on a wide range of operating experiences.

Labour costs were obtained for Ontario water treatment plants for 1973.

Sludge disposal costs were based on the haulage of sludges from 1 percent solids (typical sludge from settling tank) to 40 percent solids (typical sludge from a filter press). These sludges were considered unsuitable for agricultural land disposal and, therefore, the estimates were based on disposal at landfill sites. These costs included truck haulage, landfill operations, and property costs. The costs allowed for haulage of various solids concentrations and increased haulage distances in larger communities.

An exception to the sludge disposal costs was made for the sewerage discharge option. In this case, the sludge disposal costs were included as part of the operating costs at the sewage treatment plant.

There was no allowance made for additional administration costs.

5.3.4 Limitations of the estimated costs

Although the cost data have been derived for plants which resemble or model typical water treatment processes in Ontario, there will be a number of factors at each particular plant that are poorly represented. For instance, no allowance was made for construction difficulties such as rock. Also the mechanical equipment and chemical costs are for Southern Ontario and for remote plants they could be much greater. Therefore, caution must be used in the application of the costs to specific plants.

The costs were developed for large numbers of plants and, if used in this way, they would be reasonably accurate.

5.3.5 Waste treatment options

In preparing the capital and operating costs data for the plants under consideration, the following waste treatment process options were evaluated:

1. Direct haulage of sludge from the settling tank, with the filter backwash water returned to the settling tank.
2. Lagooning the settling tank sludge and filter backwash water, with the lagoon desludged once per year.
3. Same as 2, except the main lagoons are desludged to secondary lagoons for winter freezing of sludge with later removal of thawed sludge.

4. Disposal of waste to a sanitary sewer:
   - A. This option covers discharging water purification plant wastes within a typical bylaw limit of 500 mg/l suspended solids.
   - B. This option considers exceeding the bylaw limit to prevent hydraulic loads on the sewerage system. The sludge concentration would be low, to retain fluidity and prevent solids deposition in the sewer.
5. Filter pressing of sludge.
6. Alum recovery (turbidity treatment plants only).

Estimated cost examples for each of these options are included in Appendix VIII. These examples are for turbidity and colour treatment plants with a design capacity of 1.0 MIGPD.

5.3.6 Estimated costs versus plant design capacity

Figures 19 to 22 show the capital and total annual costs for the various waste treatment options for water plants ranging in size from 0.1 to 200 MIGPD. Separate sets of curves are shown for turbidity and colour treatment plants.

The various waste treatment options have been shown for the capacity range for which they are appropriate.

There are two constraints for which allowance has been made. These are not economic considerations but could limit the size of plant for which some options can be used.

The constraints are:

i) A limit to the number of trucks moving to and from a water purification plant site. This criterion was imposed on the assumption that residential concern would develop because of heavy truck traffic. In our considerations we assume a truck traffic of 20 round trips per eight-hour shift which is equivalent to five one-way trips per hour.
Obviously, this is not a fixed constraint because some sites will be so located as to tolerate heavy traffic. The limit shown was selected, somewhat arbitrarily, to represent

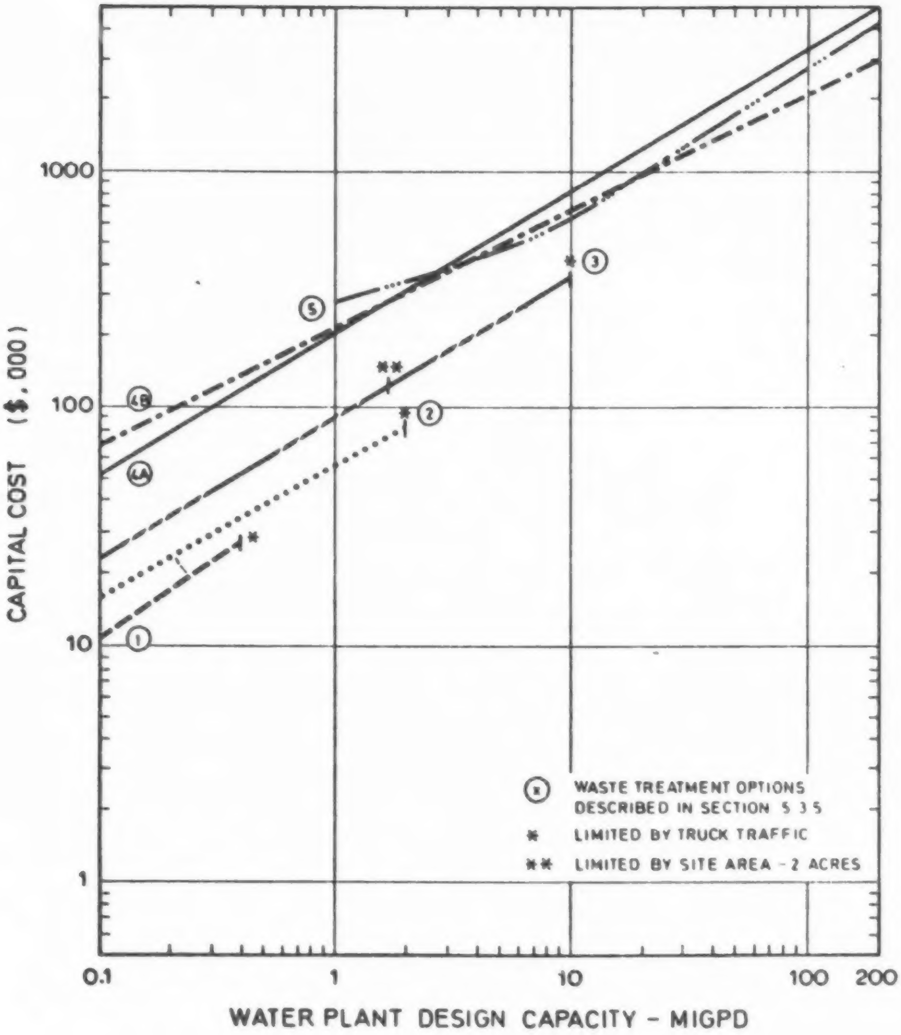


FIGURE 19. EXISTING TURBIDITY PLANTS TOTAL WASTE TREATMENT CAPITAL COSTS BASED ON MODEL AND DECEMBER, 1973 COSTS

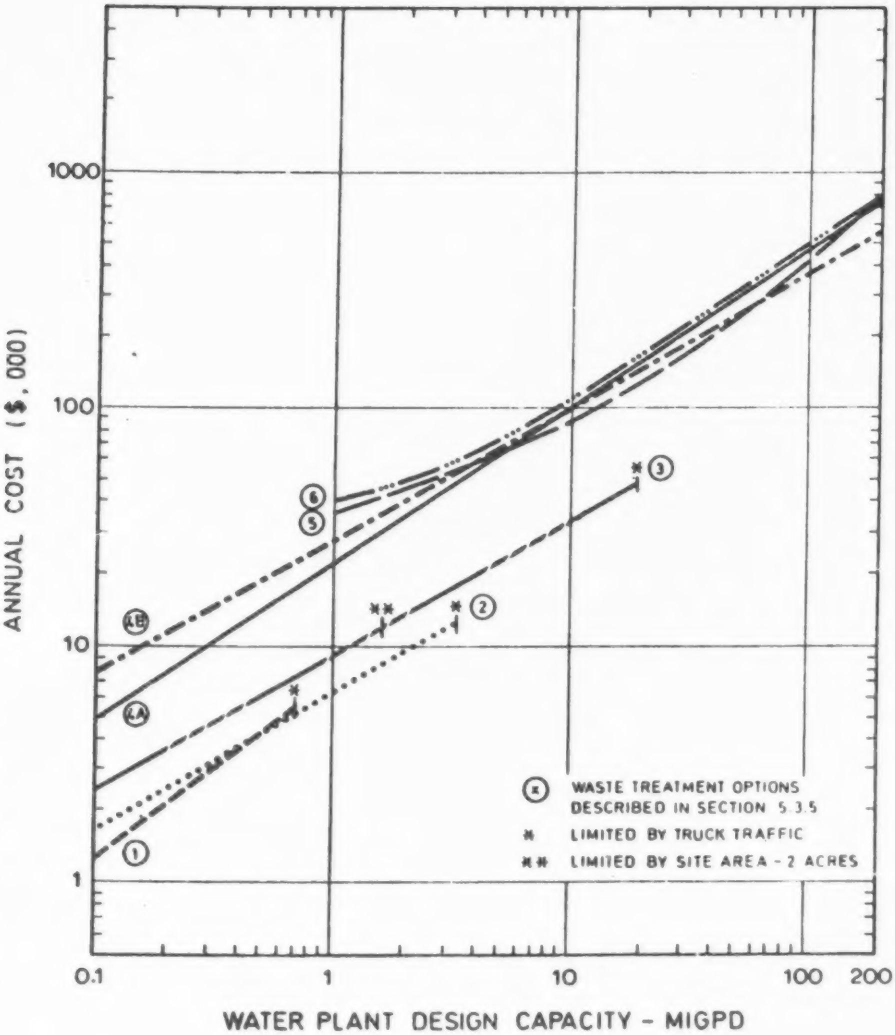


FIGURE 20. EXISTING TURBIDITY PLANTS TOTAL ANNUAL WASTE TREATMENT COST - 1973

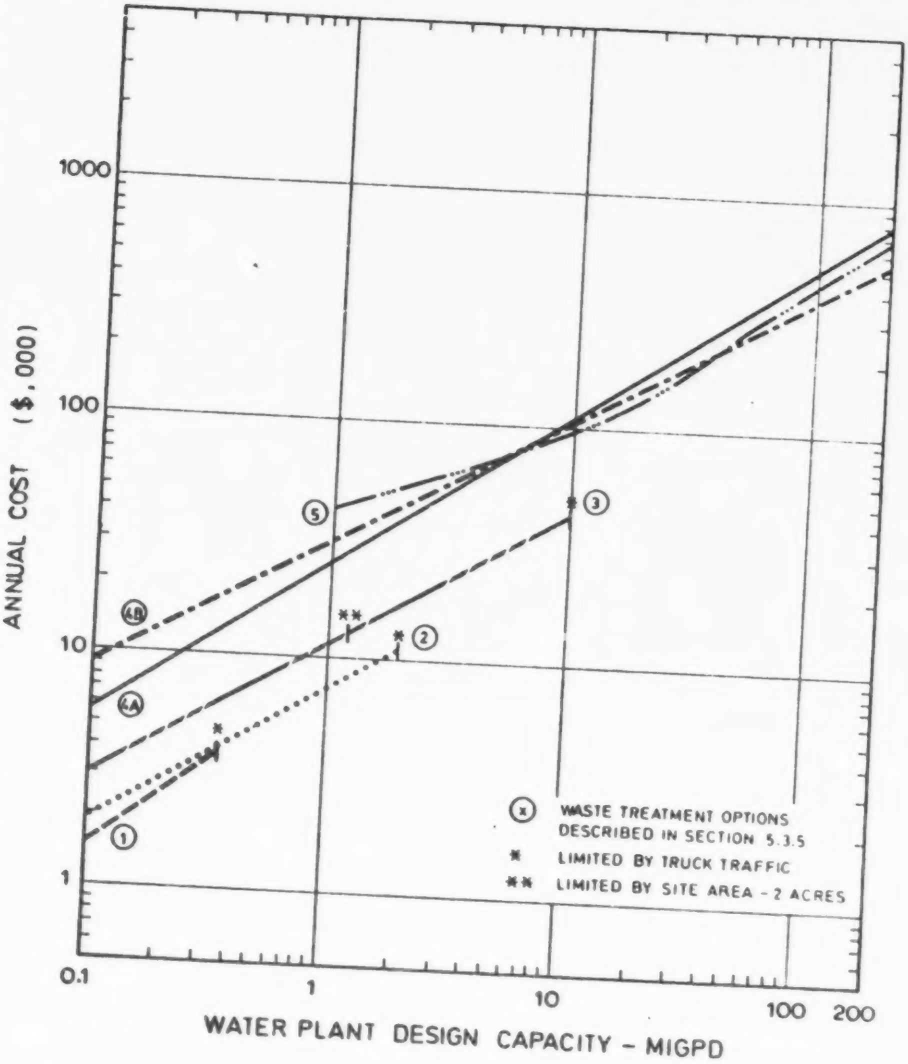


FIGURE 21. EXISTING COLOUR PLANTS TOTAL WASTE TREATMENT CAPITAL COSTS BASED ON MODEL AND DECEMBER, 1973 COSTS

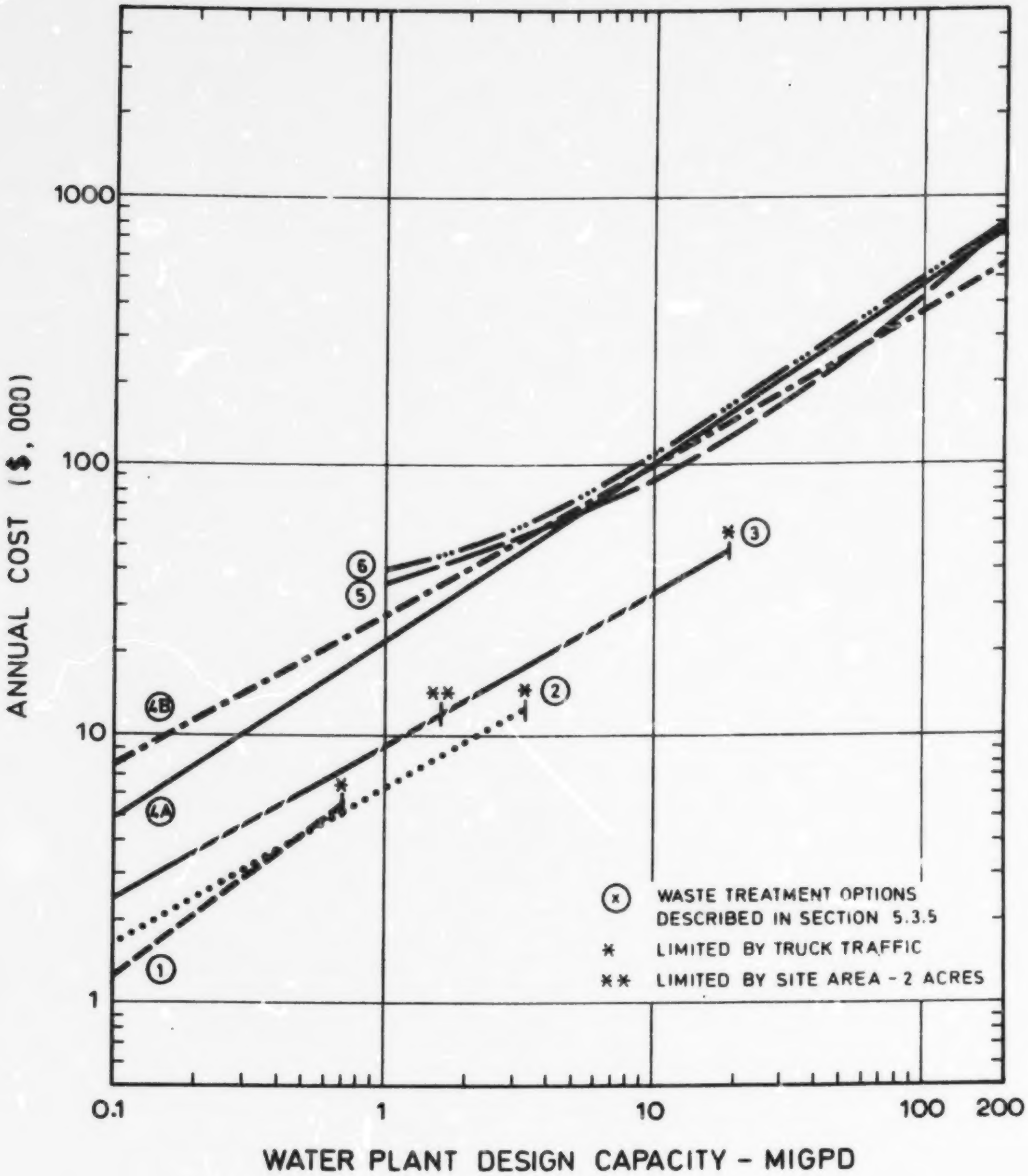


FIGURE 22. EXISTING COLOUR PLANTS TOTAL ANNUAL WASTE TREATMENT COST - 1973

a limit which might be possible throughout Ontario, considering the various aspects of intermittent versus continuous operation, highly populated versus commercial properties, etc.

ii) A limit on available land at the water treatment plants for construction of waste treatment facilities. This limit was again arbitrarily selected to strike a balance which would be applicable throughout Ontario. The maximum area which could be made available was considered to be, on the average, about two acres.

The constraints influenced only those waste treatment options which are land and/or haulage intensive.

The site limit often allowed an option to be used to a greater plant capacity than did the truck traffic limit. This was due to the options being less land than haulage intensive. In these cases, we imposed the truck limit and it only is shown on the curve.

5.3.7 Development of overall costs

To develop the overall costs for all the turbidity and colour plants in Ontario, the total annual cost curves were used to select the applicable waste treatment option for each plant. This was done by selecting the option with the lowest annual cost. Two cases were considered: the first with only the truck traffic limitation imposed; and the second with both the site size and truck traffic limitation imposed.

The capital cost was developed in a similar way, ensuring in each case that the same option was selected as used for the annual cost.

The sum of these costs for all the turbidity and colour plants for each of the two cases provide the limits of overall costs.

The turbidity and colour plants release about 96.8 percent of all the water plant waste solids produced in Ontario. The algae, iron, and hardness removal plants produce the other 3.2 percent of the solids. We have not estimated the costs for waste treatment of these other plants because they constitute such a small amount of the total. However, to develop an overall cost for Ontario, these plants have been included by prorating the sum of the turbidity and colour plants costs by the ratio of 100:96.8.

5.3.8 Total overall 1973 cost estimates

The total overall estimated costs, adjusted to December 1973 values, for water plant waste treatment for the Province of Ontario are shown below.

TOTAL CAPITAL COST	\$ 38 - 45,000,000
1973 ANNUAL COST	\$6.5 - 7,800,000

Tables 32 and 33 give the distribution of the total overall costs for various areas in Ontario.

5.3.9 Analysis of 1973 costs

Table 34 presents an analysis of the capital and annual costs for both turbidity and colour treatment plants. All the data given relate to 1973.

The yearly cost for the treatment of water purification plant wastes would be \$3.70 - \$9.00 per household.

The waste treatment costs shown in the table are effectively weighted averages for Ontario, but the range for individual plants will be from 1.9¢ to 6.1¢ per 1,000 gallons treated for plants with a design capacity range of 100 to 0.1 MIGPD.

The unit costs of \$350 - \$520 per dry ton are considerably higher than waste treatment costs of \$50 - \$100 per dry ton normally found in sewage treatment operations. This is because the water plant waste treatment unit costs reflect the large additional capital investments required for collection and control of water plant wastes as well as treatment and disposal costs. Sewage sludge treatment costs are those directly associated with treatment and disposal of the waste.

Much of the literature provides cost estimates based on a water treatment plant operating at its design capacity all year. While this condition can exist, it generally does not because of peak demands and a built-in excess capacity for growth. The unit operating costs developed using the design capacity will therefore appear low when compared to the values developed above.

TABLE 32. TOTAL OVERALL COSTS FOR WATERWAYS

Waterway	1973 Capital Cost ($000,000)	1973 Annual Cost ($000,000)
Lake Ontario	18.8 - 20.9	3.49 - 3.86
Lake Erie	4.5 - 6.4	0.74 - 1.13
Ottawa River	4.8 - 5.7	0.70 - 0.87
Southern Ontario Inland	4.3 - 5.0	0.65 - 0.79
Lake Huron	3.8 - 4.3	0.67 - 0.76
Northern Ontario Inland	1.7 - 2.4	0.23 - 0.36
Total	37.9 - 44.7	6.48 - 7.77

TABLE 33. TOTAL OVERALL COSTS FOR ONTARIO MINISTRY OF THE ENVIRONMENT REGIONS

Region	1973 Capital Cost ($000,000)	1973 Annual Cost ($000,000)
Central	13.1 - 14.0	2.47 - 2.68
West Central	6.7 - 7.5	1.20 - 1.34
Southeastern	8.5 - 11.0	1.26 - 1.70
Southwestern	7.9 - 9.7	1.32 - 1.68
Northwestern	0.5 - 0.9	0.06 - 0.15
Northeastern	1.2 - 1.6	0.17 - 0.22
Total	37.9 - 44.7	6.48 - 7.77

TABLE 34. ANALYSIS OF WASTE TREATMENT COSTS

	Turbidity Treatment	Colour Treatment
Average total flow (MIGPD)	617.6	96.7
Average total dry solids (lb/day)	62,300	20,400
Population served (approx.)	4,390,000	590,000
Total annual cost ($,000,000/yr)	4.97-5.90	1.30-1.62
Average annual cost per capita ($/capita/yr)	1.13-1.34	2.20-2.74
Average cost per 1000 gal of water treated (¢/1000 gal)	2.20-2.62	3.68-4.59
Average cost per dry ton waste solids treated ($/dry ton)	440-520	350-440

5.3.10 Estimated 1975 total costs

An estimate of total overall costs for mid-1975 may be obtained by taking an increase in construction costs of 21 percent (from December 1973 to May 1975). In addition, an annual growth rate of about 2.5 percent for Ontario population and water use increases was also included.

The estimated costs for mid-1975 are shown below:

TOTAL CAPITAL COST	$50 - 60,000,000
1975 ANNUAL COST	$ 8 - 10,000,000

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SIMCOE ENGINEERING LIMITED - W.J. Hargrave, P. Eng.

participated jointly in the preparation of this report. The Consultants were responsible for the assessment of waste treatment methods, and estimating the costs of the possible facilities and waste disposal Their results are included herewith as Sections 4.8, 5, and Appendices VII and VIII.

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APPENDIX I

Questionnaire Circulated to 105 Plants Throughout Ontario

1

THE MAGNITUDES OF WATER PLANT WASTE DISCHARGES IN THE PROVINCE OF ONTARIO

NAME OF PLANT ______________________________

LOCATION (MUNICIPALITY) ______________________________

PRESENT DAILY AVERAGE PRODUCTION (MGD) ______________________________

HIGHEST DAILY WATER PRODUCTION TO DATE (MGD) ______________________________

PLANT DESIGN CAPACITY (MGD) ______________________________

Please check the appropriate boxes or fill in information in the spaces provided if the answer is known or can be approximated to the best of your ability.

2

PART A: RAW WATER CONDITIONS

1. The raw water is drawn from a

- ☐ Lake
- ☐ River
- ☐ Reservoir
- ☐ Well or well-like system
- ☐ Other

2. (a) Raw water has an average

Turbidity (Ftu) of	Colour (HAZEN Units) of
☐ 0 - 5	☐ 0 - 5
☐ 5 - 10	☐ 5 - 10
☐ 10 - 25	☐ 10 - 20
☐ 25 - 50	☐ 20 - 40
☐ 50+	☐ 40 - 80
	☐ 80+

2. (b) With what instrument or measuring device do you determine:

(i) turbidity ______________________________

(ii) colour ______________________________

3

3. Hardness (ppm of $CaCO_3$) of	**Alkalinity (ppm of $CaCO_3$) of**
☐ 0 - 50	☐ 0 - 50
☐ 50 - 100	☐ 50 - 100
☐ 100-150	☐ 100 - 150
☐ 150 - 200	☐ 150 - 200
☐ 200+	☐ 200+

4. The turbidity

- ☐ is relatively constant
- ☐ varies seasonally
- ☐ varies widely but not seasonally

5. (a) The colour

- ☐ is relatively constant
- ☐ varies seasonally
- ☐ varies widely but not seasonally

5. (b) The filter effluent pH is: __________

4

6. (a) Average raw water conditions when peak water demands occur:

Turbidity (Ftu)	Colour (HAZEN Units)
☐ 0 - 5	☐ 0 - 5
☐ 5 - 10	☐ 5 - 10
☐ 10 - 25	☐ 10 - 20
☐ 25 - 50	☐ 20 - 40
☐ 50+	☐ 40 - 80
	☐ 80+

Do you experience any difficulty with algae?

☐ Yes ☐ No

If yes at what time of the year?

The month(s) ☐

Do you have a microstrainer? ☐ Yes ☐ No

6. (b) If yes, how many months in a year is it in use?

____

7. (a) How often are the travelling screens running?

_______________________ (hrs/day)

7. (b) What are the characteristics of the screen waste?

_______________________ (solids, algae etc.)

7. (c) Where is the screen waste disposed?

____

PART B: TREATMENT FACILITIES

1. Treatment includes:

☐ Pre-chlorination

☐ Coagulation-flocculation

☐ Precipitation Softening

☐ Sedimentation

☐ Clarifiers

☐ Filtration

☐ Other processes which are related to the production of sludges and residues. (Specify.)

PART C: CHEMICAL TREATMENT

The water is treated with:

1. Primary Coagulants

☐ Granular alum or liquid alum

☐ Ferric chloride

☐ Ferric sulphate

☐ Ferrous sulphate

☐ Polyelectrolyte (please specify)

☐ Sodium aluminate

2. Coagulant Aids

☐ Bentonite clay

☐ Sodium silicate

☐ Polyelectrolyte (please specify)

☐ Other (please specify)

3. Other

☐ Lime

☐ Soda ash

☐ Activated carbon

☐ Other (please specify)

4. The __average__ dosage of chemicals

Alum in ppm is

☐ 0 - 10

☐ 10 - 20

☐ 20 - 30

☐ 30 - 50

☐ 50+

Polyelectrolyte in ppm is

☐ 0 - 0.5

☐ 0.5 - 1.0

☐ 1.0 - 2.0

☐ 2.0+

Activated carbon in ppm is

☐ 0 - 5

☐ 5 - 10

☐ 10 - 20

☐ 20 - 50

☐ 50+

Lime in ppm (as $CaCO_3$)

☐ 0 - 20

☐ 20 - 40

☐ 40 - 120

☐ 120 - 200

☐ 200+

Activated silica in ppm is

☐ 0 - 2

☐ 2 - 4

☐ 4 - 6

☐ 6+

The average dosage of other chemicals (except those used primarily for disinfection) is:

	Chemical	Average Dosage, ppm
(1)	____________	______
(2)	____________	______
(3)	____________	______

5. The average dosage of chemicals when you are experiencing your peak demand is:

Alum	☐ ppm
Lime	☐ ppm
Polyelectrolyte	☐ ppm
Activated silica	☐ ppm
Activated carbon	☐ ppm
Other	☐ ppm (please specify)

PART D: FILTERS AND FILTER OPERATION

1. The number of filter beds currently in use is ☐ filters.

2. The dimensions of each filter bed are ☐ ft long by ☐ ft wide

OR ☐ ft in diameter.

If the filter beds are of different dimensions pleas specify.

3. The filter media is
- ☐ sand
- ☐ sand and anthracite coal
- ☐ mixed media
- ☐ other (please specify)

4. The filters are
- ☐ pressure filters
- ☐ gravity filters

5. The filters are backwashed

(i) ☐ on a fixed time schedule

☐ when the filter reaches a predetermined head loss

(ii) If they are washed on a fixed time schedule there are ☐ hours between washings.

(iii) If they are washed on a different schedule the time interval between washings is as follows:

minimum: ☐ hours

average: ☐ hours

maximum: ☐ hours

6. If headloss is measured please indicate

☐ psi ☐ feet

7. The head loss through the filter just before backwashing is:

Minimum head loss (feet)	Average head loss (feet)	Maximum head loss (feet)
☐	☐	☐

8. At what time of the year do you have shorter filter runs.

(i) we experience no problems ☐

(ii) the month(s) of ☐

9. The usual rate of backwash for one filter is:

☐ gallons per minute

If different rates are used during a single wash cycle, indicate the number of minutes at each rate.

☐ min. at ☐ gal. per minute

☐ min. at ☐ gal. per minute

☐ min. at ☐ gal. per minute

10. The time required for backwashing (not including time for running to waste after washing) is indicated as follows:

Minimum Time (minutes)	Average Time (minutes)	Maximum Time (minutes)
☐	☐	☐

11. The usual volume of water used to backwash one filter i

Thousands of gallons in winter	Thousands of gallons in summer
☐	☐

13

PART E: SLUDGE ACCUMULATION

Flocculation Basins

1. Do you have to clean your flocculation tanks? ☐
   If yes, please answer the following.
2. How many flocculation basins do you have? ☐
3. What size are the tanks?

   ☐ ft by ☐ ft by ☐ ft deep
4. How often do you clean them?

   ☐ days

   ☐ weeks

   ☐ months
5. How much sludge is in the bottom prior to cleaning?

   ☐ inches

   ☐ feet
6. How do you clean the basins?

14

Sedimentation

1. How many sedimentation tanks do you have? ☐
2. What are the length and width dimensions of the tank(s)?

   ☐ ft by ☐ ft by ☐ ft deep
3. The sludge removal following sedimentation is accomplished by:

   ☐ manual cleaning

   ☐ mechanical cleaning
4. If the basins are cleaned manually, what is the usual interval between cleanings?

   ☐ days

   ☐ weeks

   ☐ months
5. How deep is the sludge in the basin prior to cleaning?

   ☐ inches

   ☐ feet
6. How is the basin manually cleaned?

15

7. If mechanical cleaning is used, how often is the basin desludged?

   ☐ days

   ☐ weeks

   ☐ months
8. How deep is the sludge in the basin prior to cleaning?

   ☐ inches

   ☐ feet

Clarification

1. The sludge is removed from the clarifier by:

   ☐ manual blowdown

   ☐ automatic blowdown
2. How many clarifiers are there? ☐

Manual Blowdown

3. How long would your average blowdown last?
   Blowdown lasts ☐ minutes
4. How many times would you blow down the clarifier per day?

   ☐ times

16

5. Approximately how many gallons of waste would you remove in each blowdown?

   ☐ gal.
6. What is your discharge sludge settleable solids?
   After 5 min. ☐ %

   After 1 hr. ☐ %

Automatic Blowdown

7. An average blowdown would last:

   Choose one

   ☐ sec per ☐ gal.

   ☐ sec per ☐ min.

   ☐ sec per ☐ hr.

   ☐ min per ☐ hr.

   ☐ min per ☐ day
8. Approximately how many gallons of waste would there be in each blowdown?

   ☐ gal.
9. What is your discharge sludge settleable solids?

   After 5 min. ☐ %

   After 1 hr. ☐ %

PART F: DISPOSAL

1. At the present time the disposal of sludge and washwater is accomplished by:

☐ Direct discharge to a lake, river, stream bed, etc.

☐ Discharge to a municipal sewerge system

☐ Recovery of chemicals

☐ Other on-site treatment

2. Is land available near the plant which would be suitable and adequate for lagooning of wastes?

☐ Yes

☐ No

3. The approximate distance to the nearest sanitary sewer is:

☐ 0 - 100 feet

☐ 100 - 500 feet

☐ 500 - 1000 feet

☐ 1000 feet to one mile

☐ over one mile

4. The wastes flowing through the sanitary sewer descri in previous question receive

☐ no treatment

☐ chlorination only

☐ primary treatment only

☐ secondary treatment

☐ other (specify)

APPENDIX II

List of Water Treatment Plants Surveyed

Plants Sampled

Amherstburg
Belleville
Blenheim
Brantford
Cochrane
Cornwall
Deep River
Dresden
Grimsby
Haileybury
Hamilton
Kingston
Lake Huron WSS
Lindsay
Markham
Niagara Falls
Owen Sound
Ottawa-Britannia
Ottawa-Lemieux
Perth
Richmond Hill
Rockland
South Peel WSS
St. Catherines
St. Thomas
St. Jacobs
Sudbury
Thornbury
Timmins
Toronto-Island
Toronto-R.C. Harris
Toronto-Westerly
Union WSS
Windsor

Plants Visited

Ajax
Arnprior
Beamsville
Beaverton
Belle River
Bowmanville
Brockville
Burlington
Campbellford
Chatham
Cobourg
Georgetown
Goderich
Harrow
Kincardine
Meaford
Napanee
Oakville
Orillia
Oshawa
Peterborough
Picton
Port Elgin
Port Dover
Port Hope
Port Stanley
Sarnia
Smiths Falls
Trenton
Welland
Whitby

Plants Sent Questionnaires

Alexandria
Bath
Bobcaygeon
Capreol
Cayuga
Delhi
Dunnville
Eganville
Emo
Fenelon Falls
Gananoque
Hawkesbury
Huntsville
Kirkland Lake
Lakefield
Listowel
Longlac
Marmora
Mitchell
Moosonee
Niagara-on-the-Lake
Nipigon
Paisley
Petawawa
Petrolia
Port Colborne
Port Rowan
Powassan
Red Rock
Renfrew
Sioux Lookout
Southampton
Sturgeon Falls
Sutton
Tilbury
Vaughan Twp.
Vineland
Wallaceburg
West Lorne
Wheatley

APPENDIX III

Cross Reference File

Reference Topic	Reference Number
Environmental Impact	1, 2, 3, 19, 51, 52, 53, 54, 55, 66
Viscosity	5, 8, 47
Coefficient of Determination	6
Settling - pilot scale	7, 8, 47
Chemical Analyses	9, 13, 47
Water Quality Guidelines	10, 12
Discharge Guidelines	4, 11, 60, 66
Lagoons	14, 15, 17, 18, 20, 26, 40, 41, 48, 50, 59, 62
Freeze-Thaw	14, 15, 16, 17, 18, 20, 21, 22, 23, 40, 49, 50, 59, 62
Drying Beds	8, 14, 17, 20, 24, 26, 27, 40, 59
Settling - plant scale	14
Thickening	14, 15, 17, 18, 20, 25, 26, 27, 38, 40, 44, 50, 57, 58, 61
Conditioning	14, 17, 27, 43, 44, 45, 64
Filter Pressing	14, 15, 16, 17, 18, 20, 27, 28, 40, 42, 44, 45, 50, 61
Vacuum Filtration	14, 15, 17, 18, 20, 27, 28, 40, 46, 48, 49, 50, 59
Centrifugation	15, 16, 17, 18, 20, 26, 27, 39, 40, 46, 49, 50, 59
Final Sludge Disposal (landfill)	17, 18, 27, 29, 63
Sanitary Sewers	14, 15, 17, 20, 27, 30, 31, 32, 37, 40, 48, 59, 63
Recycle and/or Coagulant Recovery	14, 15, 17, 20, 27, 33, 34, 36, 38, 40, 56, 57, 58, 59, 63, 65
Alum Recovery	14, 26, 35, 36, 57

APPENDIX IV

Waste Quality Frequency Curves and 95% of the Peak Waste Discharge for Several Water Plants whose Daily Records were Examined

Waste Quality Frequency

To obtain information for compiling waste quality frequency curves for the large plants, the operating sheets for several years were examined. The time intervals for which the data were averaged varied with the production of the plant. For example, the operating conditions for the larger water plants were averaged over a seven-day period while some smaller plants (less than 20 MIGPD [90,905 m^3/day]), were averaged on a monthly basis but for a longer time.

For this work the total amount of liquid and solid waste leaving the plant was computed. In addition, waste frequency curves such as those shown in Figures 23 and 24 were constructed.

As can be seen in Figure 23, 50 percent of the time in 1973 wastewater volume was less than 1.27 MIGPD (5,773 m^3/day) while Figure 24 indicates that 50 percent of the time the pounds of dry weight solids disposed back into the waterway was approximately 5,000 lb/day (2,270 kg/day).

Peak Waste Discharge

The curves were also useful in determining the peak daily loadings on any waste collection, treatment and disposal facilities. For the 12 plants studied the average daily waste and 95 percent of the peak daily waste were determined. These values are listed in Table 35.

The 12 water plants normally discharged a total of 43,825 lb of waste on an average day. During periods of high demand and/or high raw water turbidity this discharge reached a 95 percent of peak level of 108,250 lb/day. Although it is doubtful that all plants have peak discharge periods at the same time of the year, the spring and fall storms on the Great Lakes affect most of the plants listed, very often at the same time. One plant, Toronto, R.C. Harris, on Lake Ontario normally has excellent raw water quality of less than 5 Ftu turbidity. During a storm

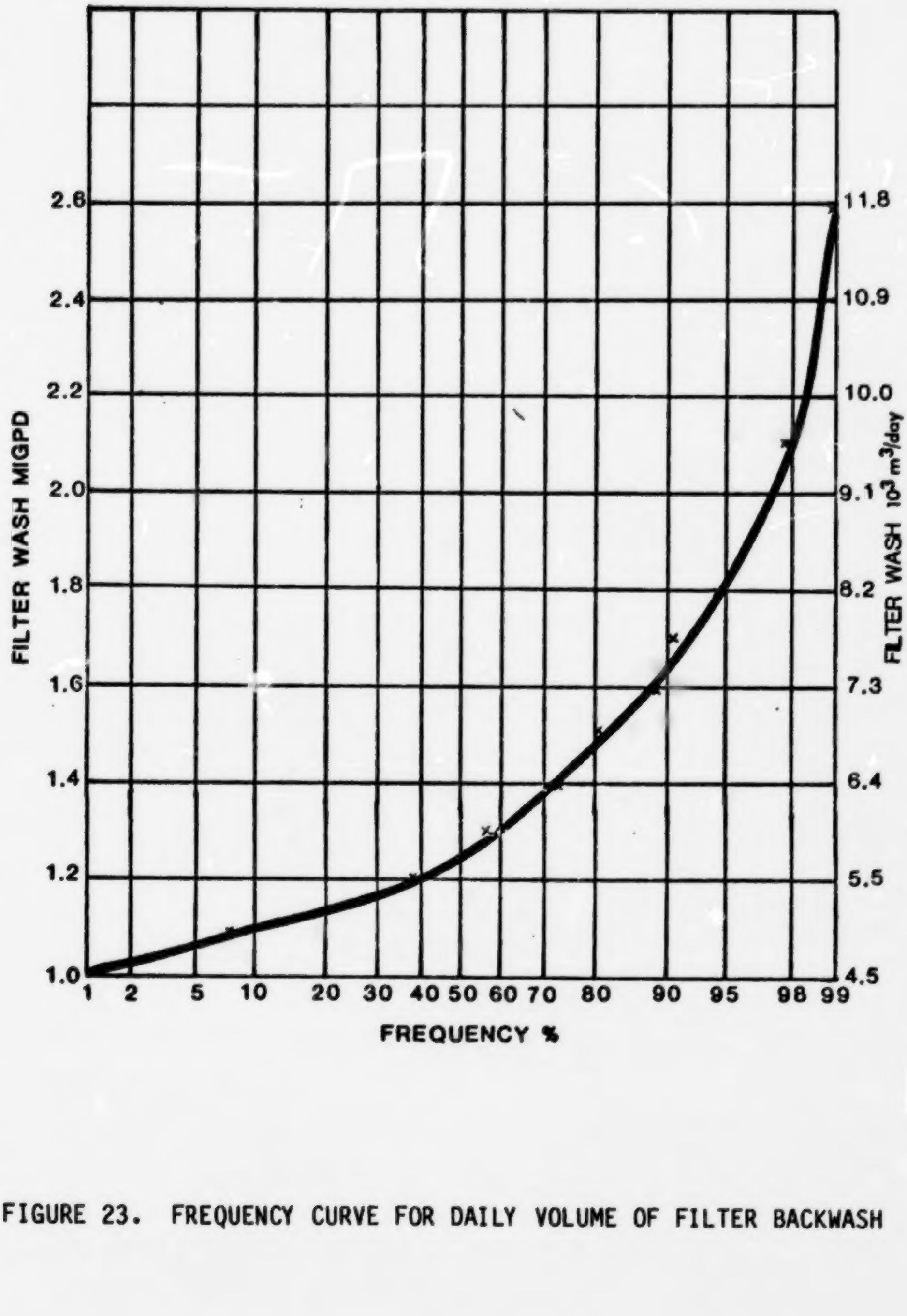

FIGURE 23. FREQUENCY CURVE FOR DAILY VOLUME OF FILTER BACKWASH

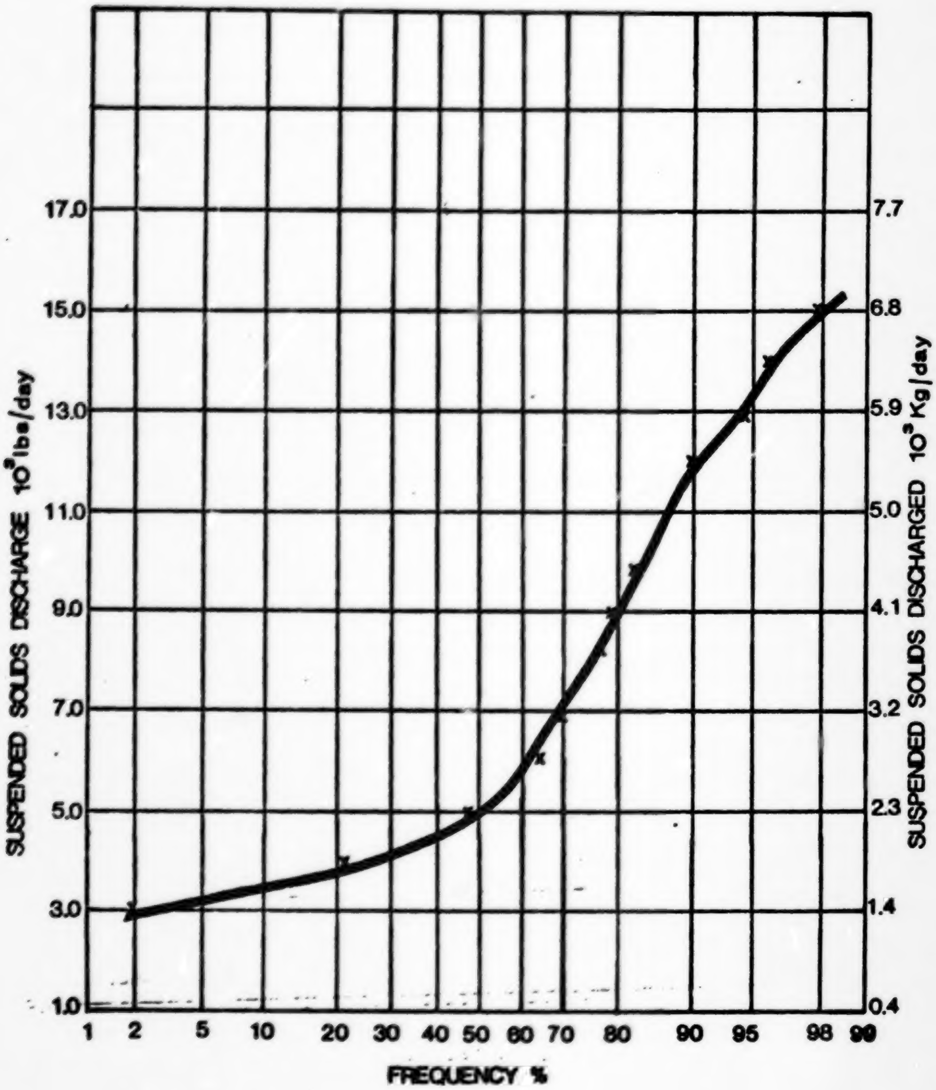

FIGURE 24. FREQUENCY CURVE FOR DAILY SUSPENDED SOLIDS DISCHARGE

TABLE 35. AVERAGE AND 95% OF PEAK WASTE PRODUCTION

Plant	Solid Waste			Liquid Waste		
	Ave. lb/day	95% Peak lb/day	% Increase	Ave. MIGPD	95% Peak MIGPD	% Increased
Elgin Area WSS	1,800	3,500	94	0.14	0.21	50
Belleville	825	1,600	94	0.13	0.17	30
Kingston	650	900	38	0.28	0.30	7
Union Area WSS	1,525	2,300	51	0.07	0.18	157
Niagara Falls	1,375	2,800	103	0.23	0.30	30
Hamilton	6,575	3,500	105	1.45	1.80	24
Lake Huron WSS	3,700	8,800	138	1.48	2.70	82
South Peel WSS	3,800	12,000	150	0.64	0.83	29
Ottawa						
- Lemieux	6,825	7,750	14	0.77	0.90	17
St. Catherines	2,750	4,600	67	0.35	0.43	23
Toronto						
- R.C. Harris	8,900	50,000	461	3.20	4.80	50
- Westerly	4,100	11,500	180	2.50	5.20	108

however the turbidity can rise to 50 Ftu. This, coupled with an increase in the coagulant dosage, greatly affected the peak weight of waste discharge

The increase in solids loadings does not necessarily mean a proportional increase in liquid waste volume however. Plants equipped with sedimentation or clarifier facilities utilize these processes to a greater extent during the time of high solids influx. Filters that may normally have been washed on a time basis well below the maximum headloss may now be washed on a headloss basis. With plants experiencing a much higher 95 percent peak liquid discharge, the problem is very often an influx of slow settling algae or plant operation at maximum hydraulic levels resulting in flow carryover onto the filters.

For those water plants where the raw water quality and chemical dosages are fairly constant during the year, there is a small percent increase (14%) in the solids waste production and in the liquid waste (17%) when slight deteriorations in raw water quality occur.

APPENDIX V

Mass Balance Methods and Results for Determining Wastewater Quantities

Mass Balance Methods

Weight of solids entering the plant

(i) Suspended solids entering - raw water. Care was taken to sample the plants when the operating conditions were close to the yearly average and the plant was operating at steady state conditions.

Raw water samples were taken to establish a relationship between the raw water turbidity as measured in Ftu on the Hach 2100A turbidimeter and the suspended solids. A reasonable assessment of the total weight of suspended solids due to the raw water entering the plant was made using the pumping rate and the suspended solids data.

(ii) Suspended solids entering - chemical addition. Samples of raw water were returned to the laboratory and dosed with the same chemicals that the plant was adding, using standard jar test procedures. After mixing, energy was applied in a manner similar to that at the plant, and suspended solids analyses were performed on the flocculated water. Details of the techniques and findings are listed in Section 2.3.2.3. The total weight of suspended solids entering the plant was then calculated in the same manner used to calculate the raw water solids.

Weight of solids leaving the plant

(i) Screens and microstrainers. The quality and quantity of wastes (sticks, algae and fish) removed by travelling screens varied widely from plant to plant. In six of 14 plants equipped with screens, the wastes were discharged to dry landfill. In the remaining eight plants, the wastes were put back into the lakes or rivers. It is felt that the nature of these wastes is such that they could be easily discharged as dry landfill at minimum charge. As a result, no further work was done in this area and the solid weight was not included in the mass balances.

Microstrainer wastes were computed in the five plants equipped with microstrainers. A sample of the microstrainer backwash water was taken for analyses. The quality of the waste varied with the algae levels.

Wastewater volumes were also difficult to calculate in several locations. For those plants where significant microstrainer waste volumes were encountered a reasonable approximation of the weight of wastes was determined from the algae concentration vs suspended solids ratio, and frequency of microstrainer use as shown in the plant records.

(ii) Sedimentation and flocculation tanks. After draining, the sedimentation and/or flocculation tank representative samples were taken in a manner described in the Water Quality Section (2.3.1.2).

The sludge depth was approximated and suspended solids determinations were carried out to compute the total sludge weight and volume. The number and size of the basins as well as the frequency of sludge removal were noted.

(iii) Solids contact clarifiers. The sampling program included six plants equipped with solids contact clarifiers out of the province total of 21. A representative sample was taken from the waste blowdown. Many of the plants (19 out of 21) were not equipped with wastewater meters and waste volume had to be measured or estimated.

Knowing the wastewater flow and the characteristics of the waste, both the volume and the suspended solids dry weight could be determined.

(iv) Filter backwash. The sampling procedure for filter waste was to take eight, 32 oz samples during the course of the backwash cycle. The samples were collected more frequently during the period of peak suspended solids (see Section 2.3.1.1).

In the case of inaccurate meters or lack of wash water meters, the backwash rates were determined with a stick gauge.

With a knowledge of the backwash flow rate, time and the corresponding suspended solids levels, the weight of solids removal from the filter was determined.

Location of solid waste removal

Table 36 outlines the point of solid waste removal within 13 plants sampled that were using sedimentation-filtration facilities, and six plants equipped with clarifiers.

The six plants using clarifiers removed 87 percent of the total suspended solid waste in the clarifier. In three cases the removal was over 95 percent. Two of the plants were new installations with pumpages well below capacity while one was a partial softening plant with extremely heavy floc. In only one location did the filters remove more solids than the clarifiers. This was attributed to the lack of proportional feeding equipment and laboratory testing equipment.

TABLE 36. SOLID WASTE REMOVAL LOCATIONS

Type of Plant	No. of Plants	% Solid Waste Removal		
		Clarifier	Sed. Basin	Filter Wash
Clarifier* Totals	6	87**	-	13
Sedimentation Basin Totals	13	-	47	53
Sedimentation Basin Size Breakdown MIGPD				
> 20	4	-	32	68
5-20	4	-	48	52
0.5-5	4	-	55	45
< 0.5	1	-	79	21

* includes both colour and turbidity removal plants

** not a weighted average %

The 13 plants equipped with sedimentation facilities removed roughly half of the suspended solids in the sedimentation basin. The four plants with greater than 20 MIGPD (90,905 m^3/day) were turbidity removal plants on Lake Erie and Ontario. The 32 percent of the solids that were removed in the sedimentation basin were believed to have accumulated during periods of high raw water turbidity, or had settled out in the dead areas of the basin(s) within the first few weeks after cleaning. The plants operate most of the year with a low raw water turbidity and the floc does not settle readily.

Of the 13 sedimentation plants listed in Table 36, four were colour removal and nine were turbidity removal. With one exception, the colour removal plants removed 70 - 90 percent of the solids in the sedimentation basin. This was probably due to the use of greater amounts of coagulants and the use of coagulant aids. The one plant that was the exception was visited within the first few weeks of its start-up and many of the operating difficulties were not ironed out.

Location of liquid waste removal

The locations of liquid waste removal for 20 sedimentation plants and the six plants with clarifiers are given in Table 37.

The plants equipped with sedimentation facilities discharged over 99 percent of the liquid waste volume originating from the filter backwashes. With many of these plants, desludging the sedimentation basins only once every four to six months (Section 3.6.1), the volume of wash water was insignificant compared to the daily backwash water volume.

TABLE 37. LIQUID WASTE REMOVAL LOCATIONS

No. of Plants	% Liquid Waste Removed		
	Sedimentation Basin(s)	Clarifier(s)	Filters
20	1	-	99
6	-	2 - 15	85 - 98

The six plants using clarifiers discharged 2 to 15 percent of the liquid waste from the clarifier(s). This was dependent on the operating conditions, particularly on the raw water suspended solids.

Mass Balance Results

The results from the 26 plants where mass balances were carried out are listed in Table 38.

The 13 water plants with conventional sedimentation facilities had an average mean deviation of 5.3% between the solids entering or leaving the system. The direct filtration plants had values in closer agreement. Those plants that included microstraining facilities and iron removal facilities had the widest deviation from the mean; fluctuating algae or iron levels might, however, explain these results.

TABLE 38. MASS BALANCE RESULTS FOR DIFFERENT TYPES OF WATER TREATMENT PLANTS

No. of Plants	Type of Plant	Weight Solids		% Average Mean Deviation
		In lb/day	Out lb/day	
13	Fl, S, F	31,300	28,000	5.3
3	Fl, F	1,750	1,950	3.8
6	C, F	3,300	3,650	7.1
4	Other	1,400	1,500	9.1

where Fl = Flocculation
S = Sedimentation
F = Filtration
C = Clarification
Other = Iron Removal, Microstrainers

APPENDIX VI

Methods of Determining Waste Quantities Based on Questionnaire Results and Comparison with Results Determined through the Daily Operating Sheets and by Mass Balance Analyses

Questionnaire Yearly Average

The waste quantity calculations were made for 77 water treatment plants based on the answers to the questionnaire. These plants were in the smaller centres lying to the outer regions of the Province.

The results from this approach were verified by comparing the questionnaire answers with the results where the daily operating sheet approach was used (12 plants) and where the mass balance approach was used (16 plants).

The breakdown of the number and size of the 77 water plants whose wastes were calculated in this manner is given in Table 39.

TABLE 39. WATER PLANTS WHOSE WASTES WERE CALCULATED USING THE QUESTIONNAIRE

Plant Size MIGPD	No. of Plants	Volume Ave. MIGPD	% of Ontario Total Treated Water Production
> 20	1	25.0	3.4
5-20	7	62.3	8.5
0.5-5	36	54.0	7.3
< 0.5	33	8.2	1.1

Waste Calculations

The method of calculating wastes from any given plant using the questionnaire was as follows:

(i) All turbidity figures were considered to be accurate. In the absence of specific yearly average turbidity data, the average of the turbidity range indicated by the operator on the questionnaire was used.

(ii) The ratio of suspended solids to raw water turbidity measured in Ftu was 1.4. This is discussed in Section 2.3.2.3.

(iii) The ratio of suspended solids to alum dosage was 0.3 to 0.5 depending on the raw water pH. This is discussed in Section 2.3.2.3.

(iv) For the iron removal plants 80 percent of the iron was assumed to be removed by oxidation and filtration and to be in the hydroxide state, unless turbidity was listed as an occurrence.

(v) The effluent leaving the filters in all the processes was assumed to contain no suspended solids.

Example calculations

Daily Treated Water Production - 2.0 MIGPD
Backwash Water - 0.2 MIGPD
Total Raw Water Treated - 2.2 MIGPD
Average Raw Water Turbidity - 2.5 Ftu
Average Chemical Dosage
- alum - 10 mg/l
- carbon - 1 mg/l

Filter Effluent pH - 7.0

Total Suspended Solids (TSS) = Raw SS + Alum SS + Carbon SS
= (2.5 x 1.4) + (10 x 0.4) + (1)
= 8.5 mg/l (8.5 lb/HTG*) (204 g/m^3)

Weight of Waste per day = Total SS x Total Raw Treated (HTG*/day)
= 8.5 x 22
= 187.0 lb/day (85 kg/day)
or = Total SS x Total Raw Treated (m^3/day)
= 204 x 416.5
= 85 kg/day

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* HTG - hundred thousand gallons

Questionnaire vs Daily Records

The calculation of the waste weight and volume using the daily records was the most accurate determination of the waste production made in this program. A comparison of the waste results previously calculated using that method and the results using the questionnaire data is given in Table 40.

TABLE 40. QUESTIONNAIRE VS DAILY RECORDS FOR WASTE QUANTITY COMPUTATIONS

Plant	Solid Wastes lb/day			Liquid Wastes lb/day		
	Daily	Quest.	% Dev.	Daily	Quest.	% Dev.
Elgin Area WSS	1,800	1,640	8.9	0.14	0.17	21.4
Belleville	825	1,050	27.3	0.13	0.12	7.7
Kingston	675	650	3.7	0.28	0.26	7.1
Union Area WSS	1,500	1,800	20.0	0.07	0.06	14.3
Niagara Falls	1,375	1,450	5.4	0.23	0.24	4.3
Hamilton	6,575	5,480	16.7	1.45	1.37	5.5
Lake Huron WSS	3,700	4,300	16.2	1.48	1.49	0.7
South Peel WSS	4,800	6,030	25.6	0.64	0.77	20.3
Ottawa - Lemieux	6,825	6,250	8.4	0.77	0.60	22.1
St. Catherines	2,750	3,600	30.9	0.35	0.48	37.0
Toronto						
- R.C. Harris	8,900	8,710	2.1	3.20	3.20	0
- Westerly	4,100	3,290	19.8	2.50	2.41	2.6
Totals	43,825	44,250	15.4*	11.24	11.17	11.9*

* Average % deviation

For the 12 plants shown in this table, the average percent deviation of the questionnaire results from the daily records results was 15.4 percent for the solid wastes and 11.9 per cent for the liquid waste. Overall, the totals of both the solid and the liquid wastes were quite close using the two different methods.

The plants with the largest percent deviation in solid wastes were those plants where algae problems were present for much of the year. The fluctuating algae level could not be accurately accounted for from the way the questionnaire was worded. Backwash water volumes results varied substantially for some plants but again the comparison between metered backwash volumes and the operator's memory of "average" operating conditions asked on the questionnaire, can explain the discrepancies.

Overall, the results using the questionnaire data were felt to present a reasonable estimate of the waste quantities involved.

Questionnaire vs Mass Balance

The 16 water plants where mass balances were carried out and summarized in Section 3.3 are listed in Table 41. The solid and liquid waste totals calculated using the questionnaire data are also given.

TABLE 41. MASS BALANCE VS QUESTIONNAIRE FOR WASTE QUANTITY COMPUTATIONS

Plant	Solid Wastes lb/day			Liquid Wastes Thousand Imp. Gal./day		
	Visit	Quest.	% Dev.	Visit	Quest.	% Dev.
Blenheim	80	82	2.5	24.9	24.7	0.8
Cochrane	1,453	1,295	10.8	28	28	0
Haileybury	126	159	26.2	30.4	30.7	0.9
Thornbury	125	121	3.2	6.0	6.0	0
Amherstburg	510	477	6.4	52	57	9.6
Deep River	158	153	3.1	50	50.4	0.8
Lindsay	675	595	11.8	200	204	2.0
Markham	12	15	25	12.8	12.7	0.8
Owen Sound	125	125	0	48	44	8.3
Perth	177	194	9.6	40	38.8	3.0
Richmond Hill	124	120	1.6	54	50	7.4
Timmins	905	900	0.5	170	170	0
Brantford	3,750	4,340	15.7	295	288	2.3
Cornwall	475	480	1.0	207	184	11.1
Sudbury	635	693	9.1	184	184	0
Windsor	5,500	4,940	10.2	1,000	1,000	0
Totals	14,830	14,689	8.5*	2,402	2,372	2.9*

* Average % deviation

For many of the plants visited and sampled under "average" conditions, the mass balance figures were very close to the results calculated from the questionnaire. Overall, the average percent difference was 8.5 percent for the weight and 2.9 percent for the volume. This was a better correlation between methods than that found using the daily records. The reason for this is felt to be that the "average" conditions under which the mass balance samples were taken were similar to the "average" conditions listed in the questionnaire. The results using either method do not include the severity and/or frequency of storms which can greatly affect overall "average" for the year.

APPENDIX VII

Water Purification Plant Models

Model Development

All values used in generating the model parameters were based on weighted mean values (weighted by 1973 reported average day flows) calculated from the data derived from the MOE survey. Weighted means were selected for use in the model to make allowance for the differences in small and large plants and to be more representative of the typical plant than were arithmetic means.

The following section shows how these parameters were developed from plants using the same type of treatment process as the model.

Water Treatment Processes

TABLE 42. TURBIDITY REMOVAL PLANT BREAKDOWN ACCORDING TO TREATMENT TYPE

Treatment Type	No. of Plants	Capacity Total MIGPD*	% of Total Flow
Sedimentation/Filtration	38	514.7	83.3
Filtration only	12	80.3	13.0
Clarification/Filtration	13	22.6	3.7
Total	63	617.6	100.0

TABLE 43. COLOUR REMOVAL PLANT BREAKDOWN ACCORDING TO TREATMENT TYPE

Treatment Type	No. of Plants	Capacity Total MIGPD*	% of Total Flow
Sedimentation/Filtration	17	84.9	87.8
Filtration only	6	4.5	4.6
Clarification/Filtration	7	7.3	7.6
Total	30	96.7	100.0

* Total MIGPD refers to summated 1973 average day capacities recorded in the survey (mid-1974).

From both of these sets of data, it is apparent that sedimentation/filtration is most significant from the standpoint of water production in Ontario.

TABLE 44. INFORMATION COMMON FOR ALL PLANTS

1973 Average Day Flow Range (MIG)	% of Total Flow	% Plants Without Sewer Access	Median Distance to Sewer (feet)	% Plants with Extra Land
0 - 0.5	1.0	23	950	54
0.5 - 5.0	10.9	12	530	53
5.0 - 20.0	14.5	8	165	42
20.0+	73.6	5	140	35
weighted average value		6.4	194	38

TABLE 45. INFORMATION FOR TURBIDITY PLANTS

1973 Average Day Flow Range (MIG)	% of Total Flow	Mean Raw Water Turbidity (Ftu)	Mean Alum Dosage (mg/l)	Design Settling Tank Overflow Rate (gpm/ft^2)	Design Filter Rate (gpm/ft^2)	Mean Flow Ratio*
0-0.5	0.6	17	18	0.62	2.04	0.46
0.5-5.0	4.7	13	15	0.77	2.38	0.60
5.0-20.0	12.2	9	10	1.00	2.70	0.40
20.0+	82.5	5	7	1.19	2.07	0.56
weighted average value		5.9	7.8	1.14	2.16	0.54

* Mean flow ratio is the 1973 average daily flow divided by the respective design capacities.

Based on the relationship between alum dose, turbidity and suspended solids developed in Section 2.3.2.3 the total suspended solids produced for the model plant will be:

$$\text{Total susp. solids} = \text{alum dose} \times \left(\frac{SS}{\text{alum dose}}\right) + \text{turbidity} \times \left(\frac{SS}{\text{Turbidity}}\right)$$

$$= 7.8 \times 0.4 + 5.9 \times 1.4 \text{ mg/l}$$

$$\text{Total susp. solid} = 114 \text{ lb/MIG } (0.0114 \text{ kg/m}^3)$$

TABLE 46. INFORMATION FOR COLOUR PLANTS

1973 Average Day Flow Range (MIG)	% of Total Flow	Mean Raw Water Colour (Hazen)	Mean Alum Dosage (mg/l)	Design Settling Tank Overflow Rate (gpm/ft^2)	Design Filter Rate (gpm/ft^2)	Mean Flow Ratio*
0-0.5	1.4	53	26	0.49	2.05	0.35
0.5-5.0	14.8	42	38	1.39	3.10	0.44
5.0-20.0	21.3	33	22	1.14	2.94	0.52
20.0+	62.5	40	38	0.84	1.68	0.63
weighted mean value		39	34	0.98	2.16	0.58

* Mean flow ratio is the 1973 average daily flow divided by the respective design flow capacity.

The weighted mean turbidity of water treated in colour plants is 4.5 Ftu and based on the suspended solids relationships detailed earlier, the solids produced will be:

$$10(34 \times 0.4 + 4.5 \times 1.4) = 199 \text{ lb/MIG } (0.0199 \text{ kg/m}^3)$$

Distribution of Solids through Process

Data were obtained during the survey on mass balances for a number of treatment plants.

For turbidity plants the sedimentation tanks removed between 10 and 77 percent, with a weighted mean value of 34.4 percent.

For colour plants the sedimentation tanks removed between 70 and 90 percent, with a weighted mean value of 73.9 percent.

Filter Backwash

To complete the model it was necessary to consider both the volume required and the frequency of filter backwash. Complete data were available for 92 of the plants, and these data are summarized in Table 27 (Section 3.6.4). The range of backwash is 2.3 to 5.8 percent of the treated water. The mean filter run time was about 41 hours.

The purpose of the model is to represent existing treatment processes, but it must allow for the plants being operated at their design capacity. Therefore, it would be inappropriate to use the survey data directly, as operating characteristics of existing plants will be different when operating at design values.

Model Backwash

Based on the average day to design day capacity ratios of 0.54 - 0.58, and a mean filter run time of about 41 hours, the filter run time prorated to design conditions will be about 23 hours. Utilizing the weighted mean design filtration rates of 2.16 gpm/ft^2 (152 m^3/m^2), a total of 3030 gallons/ft^2 (148 m^3/m^2) would be filtered between successive backwashes.

Table 47 indicates the percentage of solids remaining in the filter after different backwash volumes. These volumes are a direct function of the length of backwash; hence lower time, lower backwash volume leads to a higher degree of solids left in the filter bed. These data were calculated from information obtained at those plants where an "in-depth" study was made during the survey.

TABLE 47. INFORMATION FOR MODEL BACKWASH

Mean Accumulated Backwash Volume Gal/sq ft	Approximate % Susp. Solids Remaining in Filter	Approximate Concentration Suspended Solids in Overflow mg/l	Calculated % Backwash
90	0.5	10	2.97
83	1.0	20	2.74
72	2.0	35	2.38
62	5.0	65	2.05
51	10.0	100	1.68
36	25.0	-	1.19

The percent backwash required to achieve these degrees of filter cleaning was calculated from the volume filtered between successive backwashes.

While these values tend to be a broad range approximation, there is a clear trend and, based on the above table, a backwash of 3 percent appears to be adequate for filter cleaning. For calculations of backwash treatment component sizes, the model will, therefore, use a backwash volume of 3 percent.

APPENDIX VIII

Estimated Cost Examples

Direct Haulage From Settling Tank

Filter backwash water diverted to surge/holding tank; pumped to settling tank throughout daily work period; solids withdrawn from settling tank every three months; slurry put directly into tank trucks for haulage to suitable site.

	1.0 MIGPD* Turbidity Plant	1.0 MIGPD* Colour Plant
Capital Cost (Dec. 1973)		
1. Surge/holding tank and pumping station	31,000	31,000
2. Miscellaneous equipment (10%)	3,000	3,000
3. Piping etc. (15%)	5,000	5,000
4. Engineering (10%)	4,000	4,000
Total Capital Cost (1973)	$43,000	$43,000
Total Annual Cost (1973)		
1. Yearly carrying charges for capital debit (f = 0.1102)	4,700	4,700
2. Yearly operating/ maintenance costs		
(i) Pumping station and tank	600	600
(ii) Haulage and disposal costs (1% sludge)	1,300	2,500
Total Annual Cost (1973)	$6,600/year	$7,800/year

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* Design Capacity

On-Site Lagoons

Filter backwash and settling tank sludge diverted to a two-cell lagoon; fill and draw operation with quiescent settling of about 24 hours before supernatant is decanted to waterway; sludge is collected and removed once per year by tank truck to a suitable site.

	1.0 MIGPD* Turbidity Plant	1.0 MIGPD* Colour Plant
Capital Cost (Dec. 1973)		
1. Lagoon and general site work	20,000	25,000
2. Land for lagoon site ($20,000/acre)	13,000	17,000
3. Miscellaneous equipment (10%)	2,000	3,000
4. Piping, etc. (15%)	3,000	4,000
5. Engineering (10%)	3,000	3,000
Total Capital Cost (1973)	$41,000	$52,000
Total Annual Cost (1973)		
1. Yearly carrying charges for capital debit (f = 0.1102)	4,500	5,700
2. Yearly operating/ maintenance costs		
(i) Lagoon	600	700
(ii) Haulage and disposal costs (5% sludge)	400	800
Total Annual Cost (1973)	$5,500/year	$7,200/year

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* Design Capacity

On-Site Lagoons for Freezing

Filter backwash and settling tank sludge diverted to a two-cell lagoon; fill and draw operation with quiescent settling of about 24 hours before supernatant is decanted to waterway; sludge is pumped at various times during winter to shallow lagoons for freezing; thawed sludge removed once per year by truck to a suitable site.

	1.0 MIGPD* Turbidity Plant	1.0 MIGPD* Colour Plant
Capital Cost (Dec. 1973)		
1. Main lagoon and general site work	20,000	25,000
2. Secondary lagoon and general site work	10,000	12,000
3. Land for lagoons ($20,000/acre)	26,000	34,000
4. Miscellaneous equipment (10%)	3,000	4,000
5. Piping, etc. (15%)	5,000	6,000
6. Engineering (10%)	3,000	5,000
Total Capital Cost (1973)	$67,000	$86,000
Total Annual Cost (1973)		
1. Yearly carrying charges for capital debit (f = 0.1102)	7,400	9,500
2. Yearly operating/ maintenance costs		
(i) Main lagoon	600	700
(ii) Secondary lagoon	200	400
(iii) Haulage and disposal costs (30% sludge)	300	500
Total Annual Cost (1973)	$8,500/year	$11,100/year

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* Design Capacity

Disposal to Sewer

WITHIN 500 mg/l BYLAW LIMIT - filter backwash and settling tank sludge diverted to a surge/holding tank and pumped to sewer

MUCH GREATER THAN 500 mg/l BYLAW LIMIT - filter backwash diverted to a surge/holding tank and pumped throughout daily operation period to a thickener; the supernatant is returned to the waterway; the underflow is discharged along with the collected settling tank sludge to the sewer.

	1.0 MIGPD* Turbidity Plant		1.0 MIGPD* Colour Plant	
Capital Cost (Dec. 1973)	<500 mg/l	>>500 mg/l	<500 mg/l	>>500 mg/l
1. Settling tank collectors	58,000	58,000	65,000	65,000
2. Surge/holding tank and pumping station	31,000	31,000	40,000	31,000
3. Thickener	-	59,000	-	52,000
4. Miscellaneous equipment (10%)	9,000	15,000	11,000	15,000
5. Piping, etc. (15%)	15,000	24,000	17,000	24,000
6. Equivalent sewer and STP capacity	46,000	-	56,000	-
7. Engineering (10%)	16,000	19,000	19,000	19,000
Total Capital Cost (1973)	$175,000	$206,000	$208,000	$206,000
Total Annual Cost (1973)				
1. Yearly carrying charges for capital debit (f = 0.1102)	19,300	22,700	22,900	22,700
2. Yearly operating/ maintenance costs				
(i) Collectors	700	700	800	800
(ii) Holding tank & pumping station	600	600	600	600
(iii) Thickener	-	4,500	-	4,100
(iv) Sludge Haulage & Disposal at STP	-	100	-	300
(v) STP operating cost	700	-	1,000	-
Total Annual Cost (1973)	$21,300/yr	$28,600/yr	$25,300/yr	$28,500/yr

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* Design Capacity

On-Site Filter Press

Filter backwash diverted to a surge/holding tank with pumping station for feeding thickener throughout daily work period; supernatant from thickener returned to waterway; underflow fed to filter preparation tank; settling tank equipped with collection system for feeding sludge directly and continuously to filter preparation tank; chemical feed equipment for lime and diatomaceous earth feed to filter preparation tank and filter; filter press with filtrate returned to the waterway and the filter cake removed by truck to a suitable site.

	1.0 MIGPD* Turbidity Plant	1.0 MIGPD* Colour Plant
Capital Cost (Dec. 1973)		
1. Surge/holding tank and Pumping station	31,000	31,000
2. Thickener	58,000	52,000
3. Settling tank collectors	58,000	65,000
4. Filter press, preparation tank and feed equipment	39,000	47,000
5. Miscellaneous equipment (10%)	19,000	20,000
6. Piping, etc. (15%)	30,000	32,000
7. Engineering (10%)	24,000	25,000
Total Capital Cost (1973)	$259,000	$272,000
Total Annual Cost (1973)		
1. Yearly carrying charges for capital debit (f = 0.1102)	28,500	30,000
2. Yearly operating/maintenance costs		
(i) Pumping station & tank	600	600
(ii) Thickener	3,900	4,000
(iii) Collectors	700	700
(iv) Filter press & chemicals	1,600	2,100
(v) Haulage and disposal costs (40% sludge)	200	300
Total Annual Cost (1973)	$35,000/year	$37,700/year

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* Design Capacity

On-Site Alum Recovery

Filter backwash and settling tank sludge diverted to a surge/holding tank; fed to a thickener throughout the daily working period; the supernatant returned to the waterway; the underflow fed to a mixer where sulphuric acid is added; continuation to filter preparation tank; then through filter press; the filtrate is stored for return to the treatment process; the filter cake is removed by truck to a suitable site.

Capital Cost (Dec. 1973)	1.0 MIGPD Turbidity Plant
1. Surge/holding tank and pumping station	31,000
2. Thickener	100,000
3. Mixer	3,000
4. Settling tank collectors	58,000
5. Alum storage tankage increase	1,000
6. Filter press, preparation tank and feed equipment	25,000
7. Miscellaneous equipment (10%)	22,000
8. Piping, etc. (15%)	36,000
9. Engineering (10%)	28,000
Total Capital Cost (1973)	$304,000
Total Annual Cost (1973)	
1. Yearly carrying charges for capital debit (f = 0.1102)	33,500
2. Yearly operating/maintenance cost	
(i) Thickener	5,000
(ii) Filter press and chemicals	1,500
(iii) Collectors	800
(iv) Holding tank and pumping station	600
(v) Sulphuric acid	100
(vi) Haulage and disposal costs (40% sludge)	200
(vii) Alum credit	(300)
Total Annual Cost (1973)	$41,400/year

APPENDIX IX

Report Tables in Metric Units

ANNUAL BACKWASH WATER OF TORONTO AREA WATER PLANTS VS HUMBER RIVER DISCHARGE AFTER A SPRING RAIN

Analyses		Water Plant				Humber*
		A	B	C	D	River
Suspended Solids	mg/l	365	70	85	80	208.65
	Mkg/yr	0.64	0.27	0.09	0.50	0.45
BOD$_5$	mg/l	25	3	3	5	7.6
	kg/yr	45,100	12,500	4,000	26,500	13,000
Total Phosphorus	mg/l	1.1	1.1	0.1	0.3	0.42
	kg/yr	1,980	4,600	136	1,590	720
Kjeldahl Nitrogen	mg/l	7.5	3.5	-	3	1.5
	kg/yr	13,500	14,600	-	16,000	2,570

* Humber River totals are kg/day

TABLE 1. WATER PLANT SIZE RANGE BREAKDOWN

Size Range m^3/day	No. of Plants	Water Production 1973 Ave.	
		m^3/day	%
> 90,905	10	2,441,000	73.3
22,748-90,905	14	508,900	15.3
2,281-22,748	45	336,340	10.0
< 2,281	36	45,525	1.4
Totals	105	3,331,765	100.0

TABLE 2. WATER PLANT SURVEY BREAKDOWN

m^3/day	Number				Water Production m^3/day			
	Total	Quest.	Visit	Sample	Total	Quest.	Visit	Sample
>90,905	10	0	0	10	2,441,000	0	0	2,441,000
22,748-90,905	14	0	7	7	508,900	0	286,320	222,580
2,281-22,748	45	15	19	11	336,340	97,720	145,460	93,160
2,281	36	25	5	6	45,525	26,415	7,730	11,380
Total	105	40	31	34	3,331,765	124,135	439,510	2,768,120

TABLE 3. RAW WATER QUALITY

Raw Water Turbidity Breakdown

Turbidity Range (Ftu)	No. of Plants	Volume m^3/day	% of Total Water Produced
< 5	25	1,980,000	59.4
5 - 10	16	712,160	21.4
10 - 25	15	76,350	2.3
25 - 50	5	37,260	1.1
> 50	1	1,370	0.0

Raw Water Colour Breakdown

Colour Range (Hazen)	No. of Plants	Volume m^3/day	% of Total Water Produced
5 - 20	5	61,830	1.9
20 - 45	15	294,100	8.8
45 - 80	9	83,170	2.5
> 80	1	460	0.0

TABLE 4. CHEMICALS USED IN WATER TREATMENT PLANTS

Purpose	Chemical	Number of Plants	Weight kg/day
Primary Coagulant	Alum	81	32,000 $(Al_2(SO_4)_3\cdot($
Primary Coagulant	Polymer	1	11.5 (dry wt)
Coagulant Aid	Activated Silica	17	604 (SiO_2)
Coagulant Aid	Polymer	6*	23 (dry wt)
Taste & Odour Control	Carbon	15**	1,396
Softening or Coagulant Aid	Lime	6	772 $(Ca(OH)_2)$

* three additional plants also use polymer intermittently

** intermittent use

TABLE 14. DAILY OPERATING RECORDS - WASTE QUANTITIES

No. of Plants	Volume	Wastes	
		Solid	Liquid
	m^3/day	kg/day	m^3/day
12	2,198,000 (66.0)	19,880 (51.3)	50,900 (58.0)

( ) percent of provincial total

TABLE 15. MASS BALANCES - WASTE QUANTITIES

No. of Plants	Volume	Wastes	
		Solid	Liquid
	m^3/day	kg/day	m^3/day
16	275,000 (8.3)	6,718 (17.3)	10,900 (12.4)

( ) percent of provincial total

TABLE 16. QUESTIONNAIRE RESULTS - WASTE QUANTITIES

No. of Plants	Volume	Wastes	
		Solid	Liquid
	m^3/day	kg/day	m^3/day
77	859,110 (25.7)	12,165 (31.4)	25,932 (29.6)

( ) percent of provincial total

TABLE 17. PROVINCIAL WASTE QUANTITIES

Method of Determination	No. of Plants	Volume	Wastes	
			Solid	Liquid
		m^3/day	kg/day	m^3/day
Daily Records	12	2,197,700 (66.0)	19,882 (51.3)	50,900 (58.0)
Mass Balance	16	275,000 (8.3)	6,718 (17.3)	10,900 (12.4)
Questionnaire	77	859,100 (25.7)	12,165 (31.4)	25,935 (29.6)
Totals	105	3,331,800 (100)	38,765 (100)	87,735 (100)

( ) percent of provincial total

TABLE 18. WATERWAY WASTE BREAKDOWN

Waterway	No. of Plants	Volume m^3/day	Wastes Solid kg/day	Wastes Liquid m^3/day
Lake Ontario	26	2,309,100	17,158	50,470
Lake Erie	16	290,920	6,605	10,445
Lake Huron	9	186,370	2,474	9,990
Northern Ontario IW	14	59,080	1,453	2,280
Southern Ontario IW	31	209,050	4,743	6,820
Ottawa River	9	277,280	6,332	7,730
Total	105	3,331,800	38,765	87,735

TABLE 19. WATER PLANT REGIONAL BREAKDOWN

Region	No. of Plants	Volume 1973 m^3/day	Wastes Solid kg/day	Wastes Liquid m^3/day
Central	17	1,750,000	10,849	36,180
West Central	16	577,270	8,170	14,090
Southeastern	31	522,710	9,033	15,400
Southwestern	28	418,170	9,215	17,720
Northwestern	5	9,100	45	460
Northeastern	8	54,550	1,453	1,825
Totals	105	3,331,800	38,765	87,735

TABLE 20. MINISTRY OPERATED WATER PLANTS REGIONAL BREAKDOWN

Region	No. of Plants	Volume 1973 m^3/day	Wastes Solid kg/day	Liquid m^3/day
Central	2	163,630	2,202	3,190
West Central	2	5,900	110	460
Southeastern	4	4,080	45	0
Southwestern	7	215,900	4,004	10,440
Northwestern	1	460	9	0
Northeastern	3	16,380	370	910
Totals	19	406,350	6,740	15,000

TABLE 21. NON-MINISTRY OPERATED WATER PLANTS REGIONAL BREAKDOWN

Region	No. of Plants	Volume 1973 m^3/day	Wastes Solid kg/day	Liquid m^3/day
Central	15	1,586,350	8,647	35,010
West Central	14	571,360	8,061	13,640
Southeastern	27	518,640	8,988	15,460
Southwestern	21	202,270	5,211	7,270
Northwestern	4	8,640	36	460
Northeastern	5	38,180	1,082	910
Totals	86	2,925,440	32,025	72,750

TABLE 22. WATER PLANT SIZE VS WASTE QUANTITY

Size Range	No. of Plants	Volume 1973	Ave. Wastes	
			Solid	Liquid
m^3/day		m^3/day	kg/day	m^3/day
>90,905	10	2,441,000	22,450	58,100
22,748 - 90,905	14	508,100	8,660	16,300
2,281 - 22,748	45	337,300	6,080	10,900
< 2,281	36	45,400	1,540	2,300
Totals	105	3,331,800	38,730	87,600

TABLE 23. PRESENT WASTE DISPOSAL PRACTICES IN ONTARIO

Size Range m^3/day	Methods		
	Waterway	Sewerage	Lagoons
>90,905	10	0	0
22,748 - 90,905	12	1	1
2,281 - 22,748	37	2	5
< 2,281	36	1	0
Provincial Totals	95	4	6

TABLE 24. SEDIMENTATION BASIN SLUDGE DISPOSAL METHODS

Size Range m^3/day	No. of Plants*	Disposal		Frequency (times/year)
		Mechanical	Physical	
>90,905	8	-	8	4
22,748 - 90,905	10	1	9	5
2,281 - 22,748	19	2	17	6
< 2,281	10	1	9	6
Totals	47	4	43	5.4**

* For the remaining seven plants - no information was given on questionnaire.

** weighted average

TABLE 25. SEDIMENTATION BASIN SLUDGE VOLUMES

Turbidity Removal Plants

Size Range m^3/day	No. of Plants*	Average Sludge Volume m^3/yr	m^3/yr m^2	Cleaning Frequency times/year
>90,905	6	3,180	0.5	2.2
22,748 - 90,905	6	2,370	1.2	2.5
2,281 - 22,748	10	720	1.7	4.4
< 2,281	5	95	1.1	7

Colour Removal Plants

Size Range m^3/day	No. of Plants**	Average Sludge Volume m^3/yr	m^3/yr m^2	Cleaning Frequency times/year
>90,905	2	13,440	4.2	9
22,748 - 90,905	2	6,230	5.1	16
2,281 - 22,748	6	570	3.0	7
< 2,281	2	440	5.0	8

* 27 of 37 turbidity removal plants equipped with sedimentation basins (95 percent of turbid water flow)

** 12 of 17 colour removal plants equipped with sedimentation basins (93 percent of colour water flow)

TABLE 26. CLARIFIER BLOWDOWN PRACTICES

Size Range	NO. OF PLANTS*			
m^3/day	Manual	Frequency Range times/day	Automatic	Frequency Range times/day
22,748 - 90,905	0	-	2	33 - 144
2,281 - 22,748	1	1	7	1 - continuous
< 2,281	2	1 - 4	7	1 - 60

* No information on blowdown practices was given for 2 plants

TABLE 27. FILTER BACKWASH VOLUMES AND TECHNIQUES IN ONTARIO

Size Range m^3/day	No.*	Back-wash on Time	Back-wash at set Head-loss	Ave.** Water Fil-tered m^3/m^2	Ave.** Back-wash Water m^3/m^2	Ave.** % of Treated Water	Ave.** Filter Run (hrs)
>90,505	10	2	8	137	5.4	2.3	40
22,748 - 90,905	14	5	9	154	5.3	3.0	46
2,281 - 22,748	37	16	21	159	5.4	4.5	38
< 2,281	31	18	13	152	5.8	5.8	44
Totals	92	41	51	154***	5.5***	2.6***	41***

* No information was given in the questionnaire for the remaining 13 plants.

** Arithmetic averages

*** Weighted averages

TABLE 28. QUESTIONNAIRE RESPONSE TO:

IS SUITABLE LAND AVAILABLE NEAR YOUR PLANT FOR LAGOON(S)?

Size Range	Yes			No		
m^3/day	No. of Plants	Volume m^3/day	% of Size Range Total	No. of Plants	Volume m^3/day	% of Size Range Total
>90,905	5	854,500	35	5	1,572,670	65
22,748 - 90,905	7	200,000	42	7	278,200	58
2,281 - 22,748	20	159,070	53	18	140,000	47
< 2,281	14	20,460	54	13	17,290	46

TABLE 29. APPROXIMATE DISTANCE TO NEAREST SANITARY SEWER VS PLANT SIZE RANGE

Plant Size	0 to 30 Metres		30 to 152 Metres		152 to 305 Metres		305 to 1600 Metres		Over 1600 Metres		None		Unknown	
m^3/day	No.	Volume m^3/day	No.	Volume m^3/day	No.	Volume m^3/day	No.	Volume m^3/day	No.	Volume m^3/day	No.	Volume m^3/day	No.	Volume m^3/day
>90,905	3	750,750	2	982,800	-	-	2	327,600	2	277,550	1	104,650	0	0
22,748-90,905	6	227,500	4	181,100	2	54,600	-	-	1	13,650	1	31,850	0	0
2,281-22,748	14	107,840	6	53,700	3	21,840	6	57,790	3	31,400	6	36,860	7	28,210
< 2,281	5	8,190	3	5,000	4	5,000	5	8,190	3	2,700	6	6,370	10	10,010
Totals	28	1,094,280	15	1,222,600	9	81,440	13	393,580	9	325,300	14	179,730	17	38,220

TABLE 31. WATER PLANT BREAKDOWN BY PROCESS CLASSIFICATION

Process	No. of Plants	Total m^3/day	% of Total
Turbidity removal	63	2,807,000	84.2
Colour removal	30	440,000	13.2
Algae removal	4	53,400	1.6
Iron removal	8	31,365	1.0
Total	105	3,331,765	100

TABLE 35. AVERAGE AND 95% OF PEAK WASTE PRODUCTION

Plant	Solid Waste			Liquid Waste		
	Average kg/day	95% Peak kg/day	% Increase	Average m^3/day	95% Peak m^3/day	% Increase
Elgin Area WSS	817	1,590	94	648	960	50
Belleville	374	726	94	600	768	30
Kingston	295	410	38	1,273	1,368	7
Union Area WSS	692	1,045	51	312	816	157
Niagara Falls	624	1,270	103	1,056	1,368	30
Hamilton	2,985	1,590	105	6,603	8,164	24
Lake Huron WSS	1,680	3,995	138	6,723	12,270	82
South Peel WSS	2,180	5,447	150	2,881	3,770	29
Ottawa						
- Lemieux	3,100	3,520	14	3,506	4,082	17
St. Catherines	1,250	2,090	67	1,585	9,945	23
Toronto						
- R.C. Harris	4,040	22,700	461	14,550	21,850	50
- Westerly	1,860	5,220	180	11,360	23,630	108

TABLE 36. SOLID WASTE REMOVAL LOCATIONS

Plant Type	No. of Plants	% Solid Waste Removal		
		Clarifier	Sed. Basin	Filter Wash
Clarifier (Colour & Turbidity)	6	87*	-	13
Sedimentation Basin Size Breakdown				
>90,905	4	-	32	68
22,748 - 90,905	4	-	48	52
2,281 - 22,748	4	-	55	45
< 2,281	1	-	79	21
Sedimentation Basin	13	-	47	53

* not a weighted average %

TABLE 38. MASS BALANCE RESULTS FOR DIFFERENT TYPES OF WATER TREATMENT PLANTS

No. of Plants	Type of Plant	Weight Solids		%
		IN kg/day	OUT kg/day	Average Mean Deviation
13	Fl, S, F	14,208	12,710	5.3
3	Fl, F	794	885	3.8
6	C, F	1,498	1,657	7.1
4	Other	635	680	9.1

where Fl = Flocculation
S = Sedimentation
Other = Iron Removal, Microstrainers
F = Filtration
C = Clarification

TABLE 39. WATER PLANTS WHOSE WASTES WERE CALCULATED USING THE QUESTIONNAIRE

Plant Size m^3/day	No. of Plants	Treated Water Production m^3/day	% of Total Treated Water Production
>90,905	1	113,640	3.4
22,748 - 90,905	7	283,180	8.5
2,281 - 22,748	36	245,440	7.3
< 2,281	33	36,540	1.1

TABLE 40. QUESTIONNAIRE VS DAILY RECORDS FOR WASTE QUANTITY COMPUTATIONS

Plant	Solid Wastes kg/day			Liquid Wastes kg/day		
	Daily	Quest.	% Dev.	Daily	Quest.	% Dev.
Elgin Area WSS	817	744	- 8.9	636	773	+21.0
Belleville	374	476	27.3	590	545	- 7.7
Kingston	306	295	- 3.7	1,273	1,181	- 7.1
Union Area WSS	680	817	20.0	319	274	-14.3
Niagara Falls	624	658	5.4	1,044	1,098	4.3
Hamilton	2,985	2,488	-16.7	6,590	6,219	- 5.5
Lake Huron WSS	1,680	1,952	16.2	6,723	6,771	0.7
South Peel WSS	2,180	2,737	25.6	2,905	3,506	20.3
Ottawa						
- Lemieux	3,098	2,837	- 8.4	3,505	2,737	-22.1
St. Catherines	1,248	1,634	30.9	1,592	2,185	37.0
Toronto						
- R.C. Harris	4,040	3,954	- 2.1	14,550	14,550	0
- Westerly	1,861	1,493	-19.8	11,357	10,950	- 2.6
Totals	19,893	20,085	±15.4*	51,084	50,781	±11.9*

* Average % deviation

TABLE 41. MASS BALANCE VS QUESTIONNAIRE FOR QUANTITY COMPUTATIONS

Plant	Solid Wastes kg/day			Liquid Wastes m^3/day		
	Visit	Quest.	% Dev.	Visit	Quest.	% Dev.
Blenheim	36	37	+ 2.5	113	113	- 0.8
Cochrane	660	588	+10.8	127	127	0
Haileybury	57	72	-26.0	139	139	+ 0.9
Thornbury	57	55	- 3.3	26	26	0
Amherstburg	232	217	- 6.4	235	259	+ 9.6
Deep River	72	69	- 3.1	228	228	+ 0.8
Lindsay	306	270	-11.8	910	926	+ 2.0
Markham	5	7	+25.0	58	58	- 0.8
Owen Sound	57	57	0	218	199	- 8.3
Perth	80	88	+ 9.6	182	175	- 3.0
Richmond Hill	56			245	228	- 7.4
Timmins	411	409	- 0.5	773	773	0
Brantford	1,702	1,970	+15.7	1,340	1,309	- 2.3
Cornwall	216	218	+ 1.0	941	836	-11.1
Sudbury	288	315	+ 9.1	836	836	0
Windsor	2,497	2,242	-10.2	4,545	4,545	0
Totals	6,732	6,613	± 9.0*	10,916	10,780	± 2.9*

* Average % deviation

TABLE 42. TURBIDITY REMOVAL PLANT BREAKDOWN ACCORDING TO TREATMENT TYPE

Treatment Type	No. of Plants	Total m^3/day	% of Total
Sedimentation/Filtration	38	2,340,000	83.3
Filtration only	12	364,000	13.0
Clarification/Filtration	13	103,000	3.7
Total	63	2,807,000	100.0

TABLE 43. COLOUR REMOVAL PLANT BREAKDOWN ACCORDING TO TREATMENT TYPE

Treatment Type	No. of Plants	Total m^3/day	% of Total
Sedimentation/Filtration	17	386,200	87.8
Filtration only	6	20,500	4.6
Clarification/Filtration	7	33,300	7.6
Total	30	440,000	100.0

TABLE 44. INFORMATION COMMON FOR ALL PLANTS

1973 Average Day Flow Range m^3/day	% of Total Flow	% Plants Without Sewer Access	Median Distance to Sewer (m)	% Plants with Sufficient Land for Lagoons
< 2,281	1.0	23	290	54
2,281 - 22,748	10.9	12	162	53
22,748 - 90,905	14.5	8	50	42
>90,905	73.6	5	43	35
Weighted average value		6.4	59	38

TABLE 45. INFORMATION FOR TURBIDITY PLANTS

1973 Average Day Flow Range m^3/day	% of Total Flow	Mean Raw Water Turbidity (Ftu)	Mean Alum Dosage mg/l	Design Settling Tank Overflow Rate*	Design Filter Rate*	Mean Flow Ratio**
< 2,281	0.6	17	18	0.5	1.7	0.46
2,281 - 22,748	4.7	13	15	0.7	1.9	0.60
22,748 - 90,905	12.2	9	10	0.8	2.2	0.40
>90,905	82.5	5	7	1.0	1.8	0.65
Weighted mean value		5.9	7.8	0.9	1.8	0.54

* units in m^3/sec m^2 x 10^{-3}

** Mean flow ratio is the 1973 average daily flow divided by the respective design capacities.

TABLE 46. INFORMATION FOR COLOUR PLANTS

1973 Average Day Flow Range m^3/day	% of Total Flow	Mean Raw Water Colour	Mean Alum Dosage mg/l	Design Settling Tank Overflow Rate*	Design Filter Rate*	Mean Flow Ratio**
< 2,281	1.4	53	26	0.4	1.7	0.35
2,281 - 22,748	14.8	42	38	1.1	2.5	0.44
22,748 - 90,905	21.3	33	22	0.9	2.4	0.52
>90,905	62.5	40	38	0.7	1.4	0.63
Weighted mean value		39	34	0.8	1.8	0.58

* units in m^3/sec m^2 x 10^{-3}

** Mean flow ratio is the 1973 average daily flow divided by the respective design flow capacity.

TABLE 47. INFORMATION FOR MODEL BACKWASH

Mean Accumulated Backwash Volume m^3/m^2	Approximate % Susp. Solids Remaining in Filter	Approximate Concentration Suspended Solids in Overflow ppm	Calculated % Backwash
4.4	0.5	10	2.97
4.1	1.0	30	2.74
3.5	2.0	35	2.38
3.0	5.0	65	2.05
2.5	10.0	100	1.68
1.7	25.0	-	1.19